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UPPER TRIASSIC BRACHIOPODS AND LAMELLIBRANCHS FROM THE OMAN PENINSULA, ARABIA

by R. G. S. HUDSON and R. P. S. JEFFERIES

ABSTRACT. Norian brachiopods (4 species) and lamellibranchs (25 species, 2 subspecies) from the Asfal and Sumra Formations (Elphinstone Beds) of the Jebel Hagab area, Oman, Arabia, are critically identified, new morphological features being described. The fauna shows considerable resemblances to those of the same age from Spiti, Central Himalayas, and Indonesia, notably Misol. Brachiopods described include *Hagabirhynchia arabica* gen. et sp. nov., and *Misolia lenticulata* sp. nov. New species and subspecies of lamellibranchs are *Modiolus omanensis*, *Indopecten amusiiformis*, *I. clignetti* (Krumbeck) *asperior*, *Palaeocardita trapezoidalis* (Krumbeck) *leesi*, and *Thracia proavita*. Structural colour-banding in *Indopecten* is discussed.

THE Ruus al Jibal, the mountain range of the Oman Peninsula, is formed from a lower series of limestones and dolomites (Upper Permian to Middle Trias, 1,487 metres thick), a middle series of limestones, marls, and some sandstone (Upper Trias, 431 metres thick) and an upper series of limestone (Jurassic to Lower Cretaceous, 1,475 metres thick). The main exposure of the Upper Trias, the fauna of part of which is described in this paper, is on the east side of the peninsula where it outcrops on the western flank of the coastal anticline. It is also exposed in the northern part of the peninsula where it outcrops in the core of the Shumm Anticline on the sides of both the Elphinstone Inlet (Khor ash Shumm) and the Malcolm Inlet (Ghabbat al Ghazira). To the south on the western side of the peninsula and to the east of Ras al Khaima it outcrops on the flanks of the Hagab Monocline. There, on the southern flank, it is well exposed and accessible in Wadi Milaha and at the entrance to Wadi Bih, and it was there that the Upper Trias succession was measured and the fossils described in this paper collected.

Triassic fossils from Oman were first collected by Blanford (1872) from the Elphinstone Inlet and variously named by Stoliczka and Diener (1908*b*) as of Triassic and Lower Cretaceous age. In 1924 and 1925 G. M. Lees and Washington Gray collected from the Upper Trias of the Elphinstone Inlet and from the mountain front of the Jebel Hagab area, about 5 miles east of Ras al Khaima. These fossils were named by Lees (1928) and considered to be of Upper Triassic age, probably Norian. The 500 feet of brown limestones, shales, and sandstones from which they were collected he named the Elphinstone Beds. In the spring of 1951 R. G. S. Hudson, R. V. Browne, and Z. R. Beydoun, geologists of the Iraq Petroleum Company, measured and sampled the Elphinstone Beds of Wadi Milaha. The fossils described in this paper were then collected by R. G. S. Hudson.

From their colleagues, both in the field and in the laboratory, and from L. R. Cox of the British Museum (Natural History), the authors have received every help. To them and to the Directors and Chief Geologist of the Iraq Petroleum Company, who permitted the publication of this paper, the authors record their thanks. The fossils described in this paper have been presented to the Department of Palaeontology, British Museum (Natural History), and are referred to in this paper by their registration numbers, those of the brachiopods being preceded by the letters BB and those of the lamellibranchs by LL. Numbers preceded by the letter L are of specimens collected by G. M. Lees (1928).

[Palaeontology, Vol. 4, Part 1, 1961, pp. 1–41, pls. 1–2.]

FAUNAL STRATIGRAPHY

The general succession (Permian to Lower Cretaceous) of the Ruus al Jibal was outlined by Hudson, McGugan, and Morton (1954), its upper part (Musandam Limestone; Rhaetian to Aptian) being subsequently described by Hudson and Chatton (1959) and its lower part (Permian to Upper Trias) by Hudson (1960). In this last paper the Elphinstone Beds were redefined as a group to include the following:

	metres
Shuba Limestone and Sandstone; Upper Trias	64
Sakhra Limestone; Upper Trias	23
Sumra Limestone and Marl; Norian	56
Asfal Limestone, Marl, and Sandstone; Norian	108
Milaha Limestone; Upper Trias (Carnian–Norian)	180

The fossils described in this paper are from the Asfal and Sumra Formations only, mostly from the Sumra. All fossils from Oman discussed in this paper are from the Wadi Milaha, Jebel Hagab area, unless otherwise designated.

Asfal Beds. In the lowest 42 metres of these beds there is as much sandstone as limestone and marly shale, both usually sandy: the remainder of the formation consists of limestone and shale, very much interbedded, some of the limestones being massive and fine-grained or even calcite-mudstones. There are occasional beds of shell debris and, more rarely, entire fossils. A common fossil is *Spiriferina abichi* Oppel occurring more particularly in 4 metres of sandy marls and marly limestones, 42 metres from the base of the formation. Another common brachiopod, *Misolia*, usually *M. lenticulata* sp. nov., occurs in a nodular limestone 1·5 metres thick and 90 metres from the base. Elongate megalodontids, probably *Dicerocardium*, are abundant in the upper part of the formation notably in a feature-forming limestone, 2 metres thick and 73 metres from the base. Occasionally there are assemblages of small lamellibranchs comparable to those occurring in the Sumra Formation. Otherwise the only fossils are hydrozoans, mainly stromatoporoids, occurring in the more massive fine-grained limestones. Such a fauna occurs in the *Lovcenipora* Limestone, 3 metres thick, which forms a marked feature and is taken as the top bed of the formation.

Sumra Beds. These are mainly thin-bedded, brown-weathering, shelly limestones, and reddish-purple, yellow or brown marly shales, closely interbedded. In the 15 metres at the top of the group, shales are more common than the limestones. There are also occasional massive fine-grained limestones. The fauna is essentially one of small lamellibranchs with occasional corals. The lower part (27 metres) is marked by an abundance of *Lopha blanfordi* and is distinguished as the *Lopha* Beds: the upper part (29 metres) has an abundance of *Modiolus* and *Myophoria* and is distinguished as the *Modiolus* Beds. Corals, mainly *Thecosmilia* and *Thamnasteria*, occur at various levels, notably in the uppermost 15 metres of shales with limestones.

The brachiopod-lamellibranch fauna of the Sumra Beds is listed below (the number following the name is the number of specimens determined; * or ** indicates forms found respectively only in the *Modiolus* Beds or the *Exogyra* Beds). Numerous fossil fragments, mostly *Lopha*, were thrown away.

BRACHIOPODA: *Hagabirhynchia arabica* sp. nov., 10*; *Misolia noetlingii* (Bittner), 1*.

LAMELLIBRANCHIA: *Nucula* (*?Nuculopsis*) *misolensis* Jaworski, 1*; *Modiolus jaworskii* Wanner and

Knipscheer, 20; *M. speciosus* Merla, 3*; *M. omanensis* sp. nov., 128*; *Cassianella* cf. *subeuglypha* Krumbeck, 1*; *Aequipecten serraticosta* (Bittner), 3**; *Indopecten clignetti asperior* subsp. nov., 16; *Dimyodon* cf. *subrichtofeni* Krumbeck, 8; *Lopha blanfordi* (Lees), 40**; *Pseudolimea ?cumaunica* (Bittner), 36*; *Plagiostoma nudum* (Parona), 1**; *Costatoria omanica* (Diener), 17*; *C. ?vestitaeformis* (Krumbeck), 4**; *Myophoria verbeeki mansuyi* Reed, 1**; *Myophoria sp.* 3*; *Palaeocardita buruca* (Krumbeck), 3; *P. trapezoidalis trapezoidalis* (Krumbeck), 8*; *P. trapezoidalis leesi* subsp. nov., 1; *P. trapezoidalis* subsp. indet., 1; *Anodontophora griesbachi* Bittner, 26*; *A.* cf. *lettica* (Quenstedt), 2*; *Megalodon ?hungaricum* Kutassy, 1; *?M. rostratiforme* Krumbeck, 5*; *Pleuromya himaica* Diener, 9*; *Protocardia rhaetica* (Merian), 4*; *?Homomya sublariana* Krumbeck, 2**; *Thracia proavita* sp. nov., 3*.

THE AGE AND GEOGRAPHICAL AFFINITIES OF THE SUMRA AND ASFAL FORMATIONS

Most of the forms from Oman discussed in this paper occur in Tethyan Upper Triassic of other areas (Table 1). They range from Hungary and Lombardy in the west to the Misol Archipelago in the east, a distance of some 9,000 miles. Affinities, however, are much stronger with the Indo-Pacific region than with Europe. In the Himalayas, Sumra and Asfal forms are found from the *Juvavites* Beds to the Lower Kioto or *Megalodon* Limestone of Spiti (Diener 1908*a*, 1912), from the *Proclydonautilus griesbachi* Beds to the *Sagenites* Beds in Painkhanda (Bittner 1899; Diener 1912), and as isolated occurrences at Vihi (Kashmir), Depsang (Tibet), and Attock (West Pakistan). The *Juvavites* Beds and equivalent *Proclydonautilus griesbachi* and *Halorites* Beds are dated as Norian by their ammonites (Diener 1912, p. 94) and the *Monotis* Beds are also proved Norian by the presence of *Monotis salinaria* Bronn. There is, unfortunately, no satisfactory evidence for the age of the Quartzite Series or the overlying lower parts of the Kioto Limestone and it is at least possible that some of these horizons are Rhaetian. Subject to this qualification, however, comparison with the Himalayas suggests that the Sumra and Asfal Formations are of Norian age. The same comparison suggests that a Carnian age for the Asfal and Sumra can be excluded. The Carnian of the Himalayas, which immediately underlies the *Juvavites* and *Proclydonautilus griesbachi* Beds, is well dated by ammonites (Diener 1912, p. 87) and contains many brachiopods and lamellibranchs, but, so far as is known, is entirely without Elphinstone elements.

In Indonesia, Sumra and Asfal forms mainly occur in the *Nucula* Marl and *Athyris* Limestone of Misol and the Fogi Beds of Buru. The *Nucula* Marl and Fogi Beds are dated as Norian by ammonites related to Hallstatt Limestone forms (Krumbeck 1913, p. 117; Jaworski 1915, p. 156) and also by elements related to those of the Himalayan Norian. Comparison with Indonesia, therefore, like the Himalayas, suggests a Norian age for the Sumra and Asfal Formations.

Sumra and Asfal forms also occur in the Naiband Calciferous Sandstone of Persia, considered by Douglas (1929) to be Norian partly because the overlying Hauz-i-Khan Limestone contains European Rhaetian brachiopods.

Thus by comparison with Indonesia, Persia, Spiti, and Painkhanda, the Sumra and Asfal Formations are Norian, and this conclusion is not contradicted by the other occurrences shown in Table 1. The only possible reason for doubting this conclusion is the scarcity of well-described Rhaetian Indo-Pacific lamellibranch and brachiopod faunas. A Rhaetian lamellibranch fauna has, however, been fully described from the Napeng Beds of Burma (Healey 1908), and in it there are no Elphinstone forms.

Geographically the Sumra and Asfal Formations belong to the Indo-Pacific Province

TABLE 1

	Indonesia				*Indo-China*			*Spiti*					*Painkhanda*				*Other Himalayan localities*			*Middle East*			*Europe*			
	Nucula Marl	*Athyris* Limestone	Fogi Beds	Kanike Beds	Hoa Huynh	Yunnan	Tonkin	*Juvavites* Beds	Coral Limestone	*Monotis* Beds	Quartzite Series	*Megalodon* Limestone	*Proclydonautilus griesbachi* Beds	*Halorites* Beds	*S. griesbachi* Beds	*Sagenites* Beds	Vihi	Depsang	Attock	Naiband	Armenia	Balia	Hungary	Lombardy (Nor.)	Lombardy (?Carn.)	Europe in General
	Nor.	Nor.	Nor.	Nor.	U. Triassic			Nor.	Nor.	Nor.	?Nor.	?Nor. –Jur.	Nor.	Nor.	Nor.	Nor.	U. Trias	Nor.	U. Trias	Nor.	U. Trias	U. Trias	Nor.	Nor.	?Carn.	
Nucula misolensis	×	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Modiolus jaworskii	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Modiolus speciosus	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	×	..	..	..	..	..	..	..	..
Aequipecten serraticosta	..	..	..	..	..	..	..	×	..	×	×	..	×	×	?	?	..	..	×	..	..	..	..	..	..	..
Indopecten amussiiformis	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
I. clignetti asperior	..	×	×	..	..	..	..	?	..	?	?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Lopha blanfordi	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pseudolimea ?cumaunica	..	..	..	..	..	..	..	..	..	..	..	?	..	..	?	..	..	..	..	..	..	..	..	..	..	..
Plagiostoma nudum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	×	..
P. subvaloniense	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Costatoria ?vestitaeformis	?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Myophoria verbeeki mansuyi	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	?	?	..	..	..	..	..
Paleocardita buruca	×	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	?	?	..	..	..	..	..
P. trapezoidalis trapezoidalis	×	×	×	..	..	?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Anodontophora griesbachi	×	×	×	..	..	..	×	×	..	×	×	..	×	×	×	×	..	..	..	..	..	..	..	..	..	?
Megalodon hungaricum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	?	?	..	..
M. rostratiforme	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pleuromya himaica	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Protocardia rhaetica	×	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	×
?Homomya sublariana	..	..	×	..	..	..	..	×	..	×	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..
Hagabirhynchia ?arabica	..	..	..	..	..	..	..	..	×	×	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..
Spiriferina abichi	..	..	..	..	..	..	..	..	?	?	?	..	..	..	?	..	×	..	..	..	..	..	..	..	..	..
Misolia noetlingii	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..

with *Indopecten*, *Misolia* and *Spiriferina abichi*, and, as Lees pointed out (1928, p. 596), a near absence of European species. The claim by Douglas (1929, p. 631) that Arabia and Persia in Norian times were connected with Indonesia not via the Himalayas but by newly opened seaways through Gondwanaland is probably not justified on faunal grounds. It is true that some forms are recorded in the Middle East and Indonesia but not in the Himalayas (as *Nucula misolensis*, *Modiolus jaworskii*, the *Lopha blanfordi-parasitica* group, *Plagiostoma subvaloniense*, *Palaeocardita buruca*, *P. trapezoidalis*, and *Protocardia rhaetica*), but this may well be due to facies variation and the fact that Indonesian Norian faunas have been more extensively described than the Himalayan. The genus *Indopecten*, the distribution of which was thought by Douglas to support his views (1929, p. 631), does occur in the Himalayas as well as in Persia, Oman, and Indonesia (see later).

BRACHIOPODA

by R. P. S. JEFFERIES

Family RHYNCHONELLIDAE Gray 1848

Genus HAGABIRHYNCHIA nov.

Type species *Hagabirhynchia arabica* sp. nov.

Diagnosis. Small multicostate rhynchonellids, inversely sulcate when very small. Deltidial plates conjunct. Cardinal process present, no septalium, hinge-plate divided, even at umbo, crura radulifer, ending in broad, thin, vertically disposed plates. Weak median septum in brachial valve. In pedicle valve, strong dental plates, teeth non-denticulate, no pedicle collar.

Comparison. Of the Liassic genera discussed by Ager (1956, 1958) *Prionorhynchia*, *Cirpa*, and *Rudirhynchia* are similar enough to *Hagabirhynchia* to merit further comparison. *Prionorhynchia* Buckman resembles *Hagabirhynchia* in the numerous ribs, the weak median septum in the brachial valve, the absence of a septalium, and the form of the crura. It differs from *Hagabirhynchia* in not being inversely sulcate when young, in having the hinge-plate entire for a short distance posteriorly, in having disjunct deltidial plates, and in being larger. *Cirpa* de Gregorio, though larger, resembles *Hagabirhynchia* externally but differs (Ager 1958) in having the hinge-plate entire at the posterior margin and in having curious double deltidial plates. *Rudirhynchia* Buckman differs from *Hagabirhynchia* in having a septalium, and often a pedicle collar, and in lacking the plate-like crura. It is interesting that of these three genera *Prionorhynchia* and *Cirpa* are mainly Tethyan in distribution (Ager 1956, p. 47).

Among Moiseev's (1936) genera of rhynchonellids, *Robinsonella* is externally almost identical to *Hagabirhynchia* but differs internally in having the hinge-plate entire for a considerable distance posteriorly, and in the form of the crura.

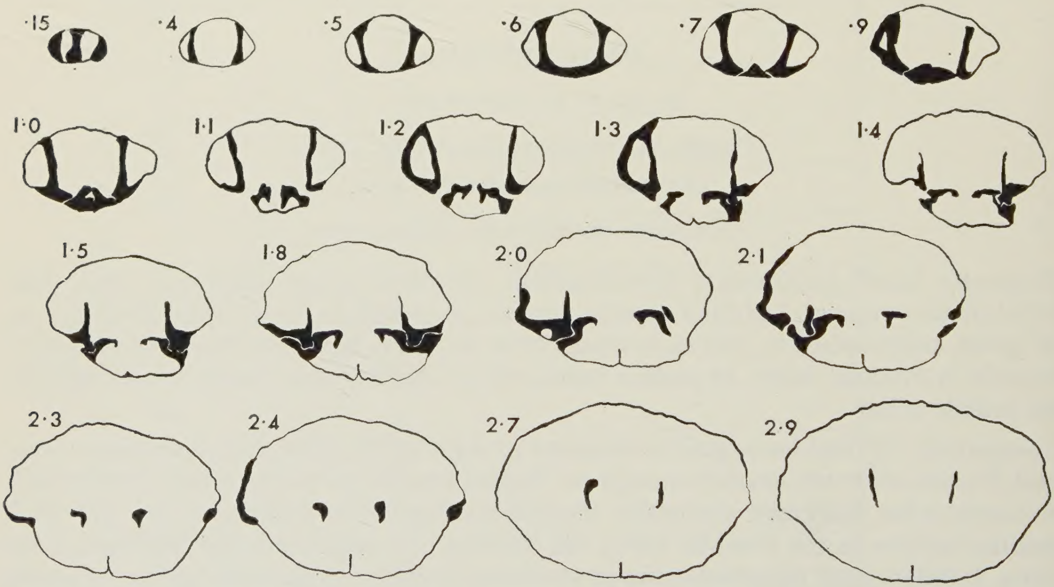
On external characters alone *Hagabirhynchia* would include some if not all of the small, multicostate rhynchonellids of *liasischem Habitus*, placed in the *Rhynchonella subrimosa* and *R. fissicostata* group by Bittner (1890, p. 313). The internal structure of *R. subrimosa*, as far as known (Zugmayer 1882, p. 37, pl. 14, fig. 12), is also like that of *Hagabirhynchia*.

Hagabirhynchia arabica gen. et sp. nov.

Plate 1, figs. 18–21; text-fig. 1

Holotype. BB20248 (Pl. 1, figs. 18–21). *Paratypes*. BB20249 (text-fig. 1), BB20512–19. *Modiolus* Beds, Sumra Formation.

Description. Length (BB20248, holotype) 10 mm., breadth 11 mm., thickness 6 mm. Apical angle about 95°. Anterior commissure with normal arched sulcus in adult but with weak inverted sulcus (norelliform stage) when very young and rectimarginate at 3–5 mm. from the brachial umbo. Ribs present even at the umbones, often forking once or twice during ontogeny, particularly near the median line. In adult about seventeen ribs in the brachial valve, one less in the pedicle valve, three to four ribs present on floor of sulcus in pedicle valve (four in holotype), one more on central fold in brachial valve. Beak suberect; beak ridges strong. Deltidial plates conjunct; foramen circular, hypothyrid.



TEXT-FIG. 1. Serial sections of *Hagabirhynchia arabica* gen. et sp. nov., ×5. BB20249, *Modiolus* Beds, Sumra Formation. Numbers are distances in mm. from apex of pedicle valve.

Internal structure as for genus (see text-fig. 1). Muscle scars unknown.

Comparison. *H. arabica* is either identical to, or an external homeomorph of, *Rhynchonella bambanagensis* Bittner (1899, p. 44, pl. 8, fig. 4, p. 56, pl. 9, fig. 18; Diener, 1908*a*, p. 128, pl. 23, fig. 8) from the Himalayan Norian. One particular point of resemblance is the distinct inverted sulcus in the very early growth-stages as shown by the specimen of *R. bambanagensis* figured by Diener (1908*a*, pl. 23, fig. 8). However, the internal structure of the Oman specimens justifies a new genus and since it would be unwise to make *R. bambanagensis* the genotype of this genus because its internal structure is unknown and its identity with the Oman material therefore uncertain, the Oman specimens are here allocated to a new species.

H. arabica externally resembles *Rhynchonella levantina* Bittner (1891, p. 107, pl. 1, figs. 1–3) except that this latter species has a more acute apical angle. Externally it is also very similar to *Robinsonella mastakanensis* Moiseev (1936) but this species differs internally (see under genus above).

H. arabica occurs in the Sumra Formation of Oman where it is fairly common. It has been considered to be possibly identical with *Rhynchonella bambanagensis* Bittner which occurs in the Coral Limestone, *Monotis* Beds and Quartzite Series of Spiti, and the *Spiriferina griesbachi* Beds of Painkhanda, all of which formations are Norian in age.

Family SPIRIFERINIDAE Davidson 1884

Genus SPIRIFERINA d'Orbigny 1847

Spiriferina abichi Oppel

Plate 1, figs. 13–17, 22, 23; text-fig. 2

Spiriferina abichi Oppel 1865, p. 298, pl. 88, figs. 6*a*, *b*.
Spirifera vihiana Davidson 1866 (Jan. or Feb.), p. 41, pl. 2, fig. 4.
Spirifera kashmeriensis Davidson 1866 (Jan. or Feb.), p. 41, pl. 2, fig. 5.
Spirifer Tibeticus Stoliczka 1866 (Sept. or later), p. 28, pl. 3, figs. 1, 2.
Spirifer altivagus Stoliczka 1866 (Sept. or later), p. 28, pl. 3, fig. 3.
Spiriferina Griesbachi Bittner 1899, p. 51, pl. 9, figs. 1–13; Diener 1908*a*, p. 121, pl. 22, figs. 7–13.

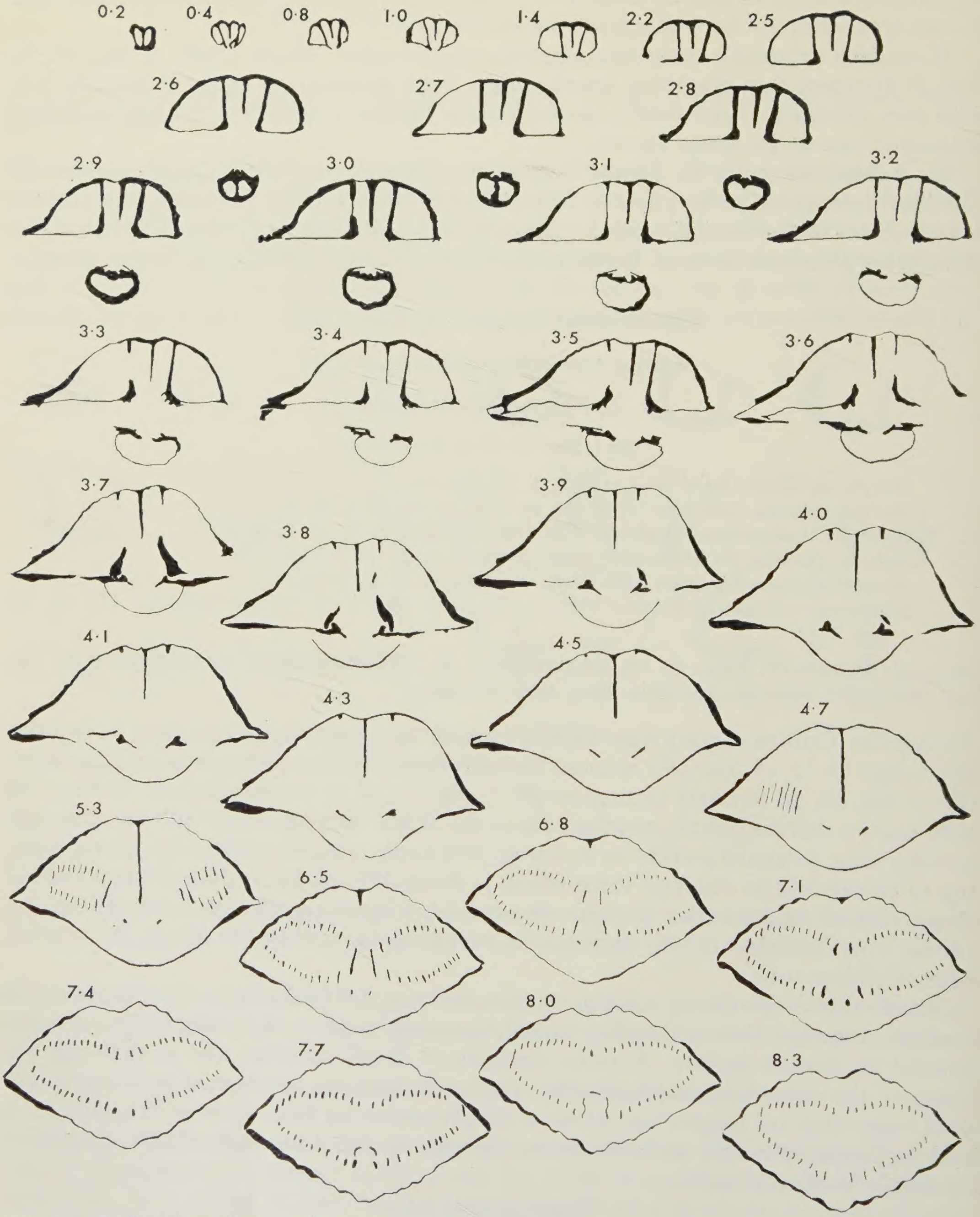
Material. BB20490 (Pl. 1, figs. 13–17), BB20491 (Pl. 1, fig. 23), BB20492–500, BB20501 (Pl. 1, fig. 22), and BB20502–7. All from *Spiriferina* Bed, Asfal Formation.

Description. Outline varying from slightly broader than long without cardinal extremities (Pl. 1, figs. 13–17, cf. *Spirifera vihiana*), through forms with produced cardinal extremities (Pl. 1, fig. 23), to strongly transverse (Pl. 1, fig. 22, cf. *S. kashmeriensis*). Delthyrium with narrow deltidial plates meeting only at the umbo. Brachial valve with low area and notothyrium. Sulcus of pedicle valve strong, with single, angular, median rib, corresponding to strong fold in brachial valve which is divided by single median furrow. Lateral slopes with about ten rather angular ribs separated from area of both valves by narrow ribless zone. Number of ribs increases in ontogeny by appearance of ribs at anterior edge of ribless zone.

Pedicle valve with strong median septum touching deltidial plates where these are in contact at umbo. Dental lamellae strong, reaching to floor of pedicle valve, roughly parallel to median septum. Anterior margins of dental lamellae and median septum concave, the septum extending farther anteriorly than the lamellae. Cardinal process bifid, supported on hinge-plate which is clearly separated from floor of brachial valve and supported by weak, median septum. Spiralia of about fourteen whorls, connected by simple U-shaped jugum.

DIMENSIONS (in *mm.*)

	Length	*Breadth*	*Thickness*
BB20490 (without produced cardinal extremities)	14·7	20·3	15·2
BB20503 (with produced extremities)	17·3	23·6	12·2
BB20501 (transverse form)	19·4	*c*.35	14·8



TEXT-FIG. 2. Serial sections of *Spiriferina abichi* Oppel, ×1·5. *Spiriferina* Bed, Asfal Formation. Where the external shell has been dissolved, a thin line represents the contact between the external matrix and the infilling. Numbers are distances in mm. from the apex of the pedicle valve.

Remarks. The nomenclature of this species is extremely confused but the name *Spiriferina griesbachi* Bittner, by which it is usually known, is certainly invalid.

Bittner himself remarked (1899, p. 52) that his species *S. griesbachi* was probably identical with *Spirifer tibeticus* and *S. altivagus* Stoliczka 1866: the probability of their identity was strengthened by von Krafft (1900, p. 223) who showed that Stoliczka's specimens were probably from the Coral Limestone (= *Spiriferina griesbachi* Bed) of Spiti. Bittner also noticed the resemblance between *Spiriferina griesbachi* and *Spirifera vihiana* Davidson 1866, which, though supposedly Carboniferous at the time of description, came from an area (Vihi in Kashmir) where Upper Triassic rocks were later found (Middlemiss 1909). *Spirifera kashmeriensis* Davidson 1866, though much more transverse than *S. vihiana*, is nevertheless probably conspecific. This view is based firstly on the fact that Davidson's figured specimens (here respectively designated holotypes) of *S. kashmeriensis* and *S. vihiana* occur on the same block, B82126, together with other fragments of *Spiriferina* and secondly on the existence of a transition between normal and transverse forms, noticed by Diener in *Spiriferina griesbachi* (1908*a*, pl. 22, figs. 7–12) and now confirmed from the Oman material.

Davidson's names (*vihiana* and *kashmeriensis*) have priority over Stoliczka's names (*altivagus* and *tibeticus*) since they were published in the first part of Vol. 22, *Quart. J. Geol. Soc. London*, which appeared before 16 February 1866 (Council Report, *Q.J.G.S.* vol. 22, p. i), Stoliczka's work being published in Memoir 5 of the Geological Survey of India with Oldham's covering letter to the volume dated September 1866.

However, the valid foundation by Oppel (1865) of *Spiriferina abichi* seems to have escaped the notice of Bittner. Oppel based his description on a single pedicle valve whose age was unknown; its identity to *tibeticus*, *altivagus*, *vihiana*, *kashmeriensis*, and *griesbachi* is scarcely in doubt, however, since, besides the apparent identity of form and ribbing, there is also similarity of age, the village of Tingti where *S. abichi* was found being now known to be situated in the marine Triassic outcrop of Spiti.

The internal structure of *S. abichi* from Oman is almost exactly like that of the type species of the genus, *S. walcotti* (Sowerby). The latter, however, because of the low convexity of the brachial valve, has a very much smaller space between the floor of the valve and the hinge-plate, and the median septum of the brachial valve, which is weak in *S. abichi*, is sometimes absent in *S. walcotti*. These differences are not of generic value and *S. abichi* is therefore confirmed as a *Spiriferina* (*s.s.*).

Three other Triassic spiriferinids closely resemble *S. abichi*, particularly in the presence of a rib in the median sulcus. These are *S. moscai* Bittner (1892, p. 80) from the Upper Trias of Anatolia, *S. lipoldi* Bittner (1890, p. 139) from the Ladinian and Carnian of the Alps, and *S. subgriesbachi* Krumbeck 1924 from the Upper Trias of Timor. Of these *S. subgriesbachi* differs from *S. abichi* in being smaller, having coarser growth-lines and fewer but coarser ribs. Its internal structure is unknown but Krumbeck, as the name implies, closely related it to *S. abichi*. *S. lipoldi* resembles *S. abichi* externally but has no dental lamellae and so cannot be closely related. *S. moscai*, on the other hand, has strong dental lamellae and must be close to *S. abichi*, particularly to the more transverse variants. It differs from these latter, however, in its more rounded lateral extremities and in having fewer (about five) more rounded ribs on the lateral slopes.

The Oman specimens of *S. abichi* are smaller than typical specimens from the *gries-*

bachi Bed of the Himalayas, but the Indian populations of the species vary in size (Diener 1908*a*, p. 121).

S. abichi thus occurs in the Asfal and Sumra Beds of Oman, the Triassic of the Vihi district, Kashmir, the *S. griesbachi* Beds of Painkhanda, and the Coral Limestone, *Monotis* Beds, and Quartzite series of Spiti.

Family ATHYRIDAE Davidson 1884

Genus MISOLIA von Seidlitz 1913

Misolia noetlingii (Bittner)

Plate 1, figs. 5–8

Spirigera? Noetlingii Bittner 1899, p. 68, pl. 11, figs. 2, 3; Diener 1908*a*, p. 135, pl. 24, figs. 1, 2; ?Merla 1933, p. 111, pl. 5, fig. 4.

Misolia noetlingi (Bittner). Seidlitz 1913, p. 191.

Material. BB20240 (Pl. 1, figs. 5–8), BB20242, BB20520, *Misolia* Bed, Asfal Formation; BB20241, *Modiolus* Beds, Sumra Formation.

The Oman specimens agree very well externally with those figured by Bittner and Diener though the umbones cannot be compared since they have been damaged in the Oman specimens. Apart from the fact that spiralia are definitely present the complicated internal structures described by Seidlitz (1913) in *M. misolica* from the *Athyris* Limestone of Misol could not be proved in the Oman material. *M. noetlingii* is thus referred to its genus mainly on external features.

EXPLANATION OF PLATE 1

All figured specimens are from the Elphinstone Beds, Upper Trias, of Wadi Milaha, Jebel Hagab area, near Ras al Khaima, Trucial Oman, Arabia. All, except those of figs. 1–4, were coated with ammonium chloride before photography.

Figs. 1, 2, 3. *Indopecten clignetti asperior* subsp. nov. *Modiolus* Beds, Sumra Formation. 1, Right valve, LL314, ×1·5, holotype. 2, Left valve, LL315, ×1·5, paratype, showing *Indopecten* structure and the introduction of a radial geniculation just anterior to the posterior row of tubercles. 3, LL321, ×10, Showing *Indopecten* structure in part of shell where the calcitic layer has mostly been removed but persists in the zigzag thickenings.

Fig. 4. *Pseudolimea ?cumaunica* (Bittner). LL375, ×10. Right valve showing secondary ribs in the troughs between slightly abraded radial folds, and raised growth-lines considerably stronger than the radial striae. *Modiolus* Beds, Sumra Formation.

Figs. 5–8. *Misolia noetlingii* (Bittner). BB20240, ×1·5. Shell missing from near umbo of brachial valve. *Misolia* Bed, Asfal Formation.

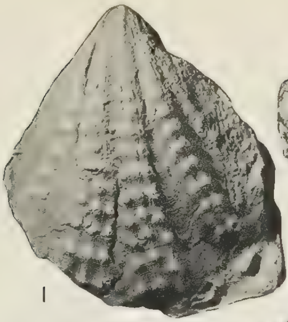
Figs. 9–12. *Misolia lenticulata* sp. nov. Holotype, BB20243, ×1·5, slightly crushed. *Misolia* Bed, Asfal Formation.

Figs. 13–17. *Spiriferina abichi* Oppel, form without produced cardinal extremities, cf. *S. vihiana* (Davidson). BB20490, ×2·5, decorticated near brachial valve umbo. *Spiriferina* Bed, Asfal Formation.

Figs. 18–21. *Hagabirhynchia arabica* gen. et sp. nov., holotype, BB20248, ×2·5. *Modiolus* Beds, Sumra Formation.

Fig. 22. *Spiriferina abichi* Oppel, transverse form, cf. *S. kashmeriensis* (Davidson), BB20501, ×2·5. *Spiriferina* Bed, Asfal Formation.

Fig. 23. *Spiriferina abichi* Oppel, rather narrow form with produced cardinal extremities. BB20491, ×2·5. Decorticated near brachial umbo. Note *Dimyodon* on area. *Spiriferina* Bed, Asfal Formation.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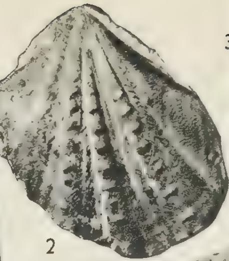
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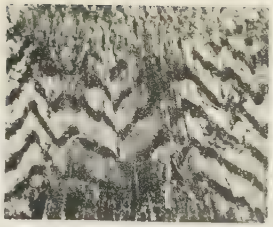
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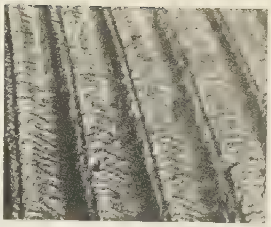
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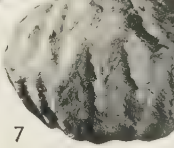
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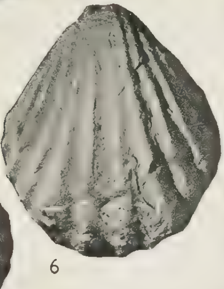
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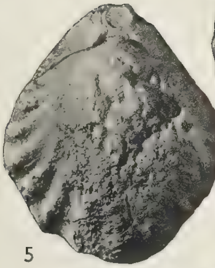
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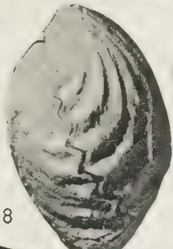
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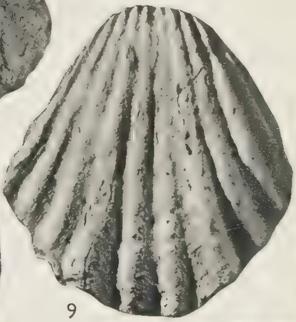
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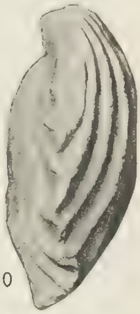
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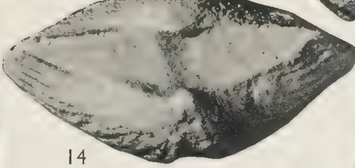
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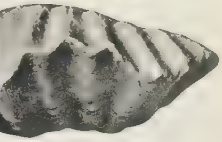
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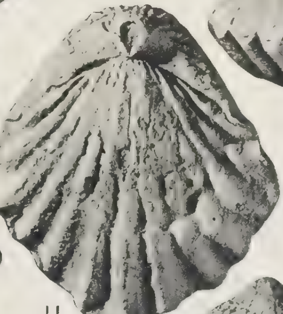
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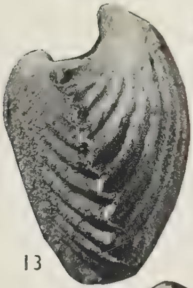
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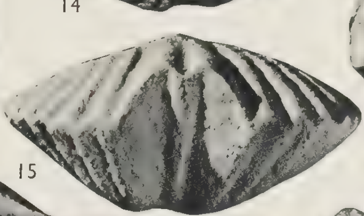
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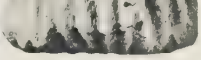
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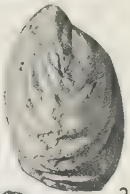
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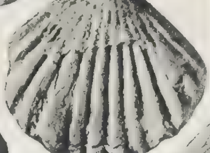
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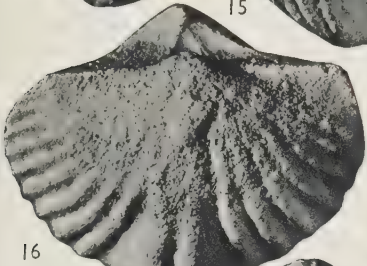
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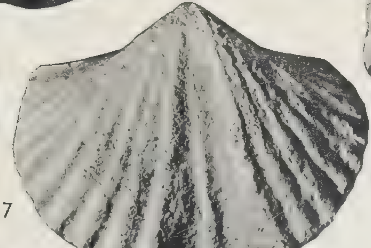
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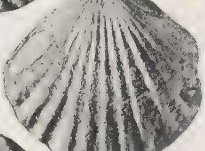
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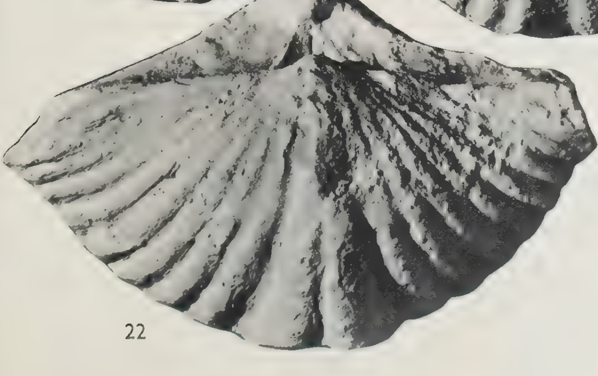
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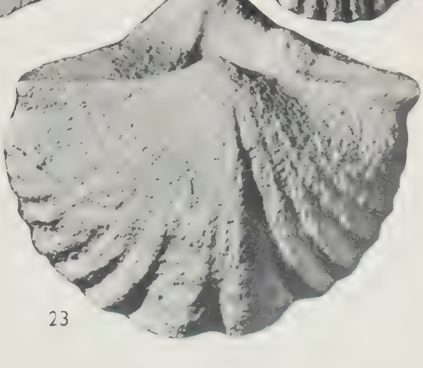
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HUDSON AND JEFFERIES, Noric brachiopods and lamellibranchs

M. noetlingii is more tumid, narrower, and more strongly sulcate than *M. lenticulata* sp. nov., *M. maniensis* (Diener), or *M. maniensiformis* (Diener), and its ribs are coarser than even the coarsest ribbed specimens of *M. misolica* Seidlitz. The *Misolia* which Krumbeck (1913, p. 30) compared with *M. noetlingii* has more ribs which fork more often and is less tumid and less deeply sulcate. *M. noetlingii* lacks the characteristic asymmetry of *M. asymmetrica* Wanner, Knipscheer, and Schenk (1952, p. 72) which is also present in the various species of *Misolia* described by Kutassy (1934). *M. noetlingii* is longer and more tumid than *M. pinajae* Krumbeck (1923, p. 327) and lacks the crenulations on the ribs of *M. aspera* Krumbeck (1924). *Spirigera tricupii* Bittner 1892 is like *M. noetlingii* in general shape but has no ribs in the sulcus. The specimen which Merla (1933, p. 111) identified as *M. noetlingii* is not typical since it has three ribs instead of two in the median sulcus.

Apart from Oman, *M. noetlingii* is thus only known from the *Megalodon* Limestone of Spiti.

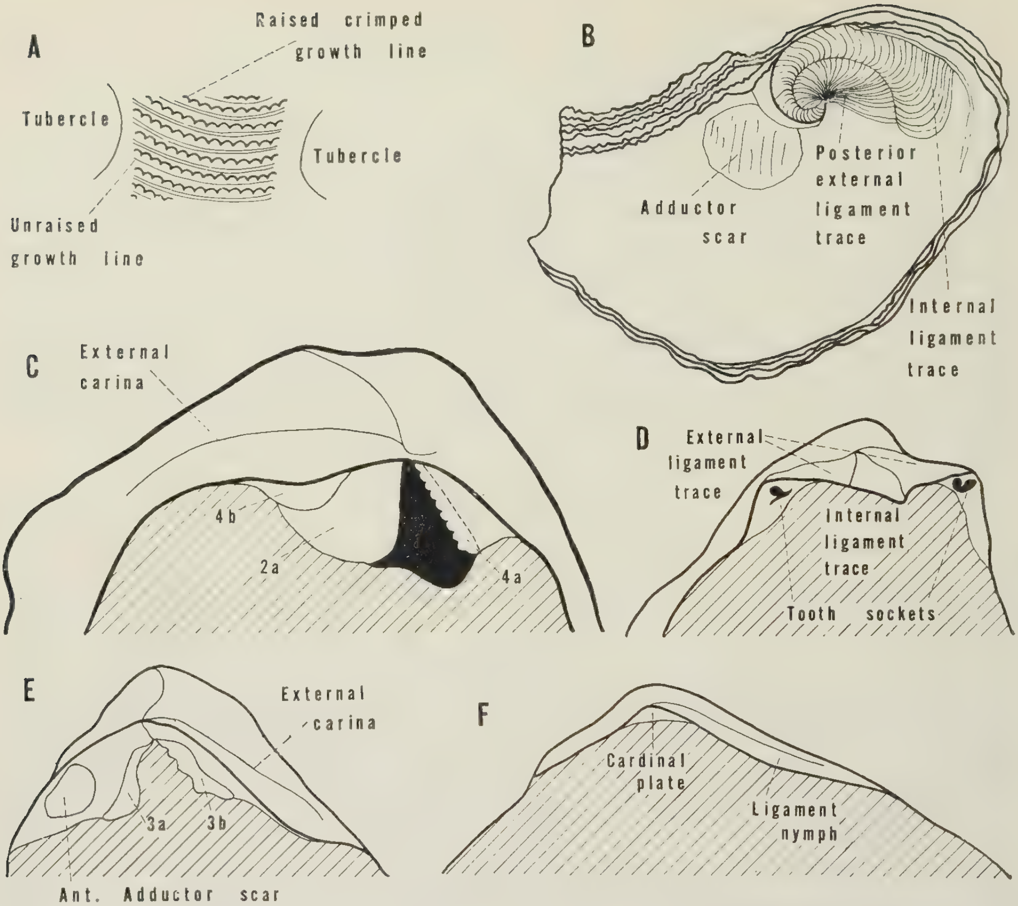
Misolia lenticulata sp. nov.

Plate 1, figs. 9–12

Holotype. BB20243 (Pl. 1, figs. 9–12). *Paratypes*. BB20244–7, BB20521–48. All from *Misolia* Bed, Asfal Formation.

Description. Shell terebratuliform, both valves of low but about equal convexity. Dimensions (BB20243, holotype): length 28 mm., breadth 26 mm., thickness 12 mm. Sulcus of pedicle valve shallow; linguiform process not prominent. Median fold of brachial valve weak. Two ribs in sulcus of pedicle valve correspond to two furrows separating three ribs on median ridge. Lateral slopes with five or six ribs on each valve on each side, the number of ribs increasing in ontogeny by addition of ribs near the umbo. On material seen the ribs do not branch. Concentric growth-lines weak. Beak erect to sub-erect without beak ridges. Pedicle opening large, permesothyrid. Strong subparallel dental lamellae and distinct hinge-plate present: fragments of spiralia also observed. Other features not ascertainable in specimens examined.

Remarks. This species is less tumid than *M. noetlingii* Bittner. Probably the most closely related species is *M. maniensiformis* Diener (1908*a*, p. 126). The latter, which was based on one specimen from the Quartzite Series of Spiti, is similar to *M. lenticulata* in having two ribs in the sulcus and in its low convexity. It differs by being more strongly sulcate and perhaps by having fewer ribs on the lateral slopes (three instead of about five). *M. aspera* Krumbeck 1924 resembles *M. lenticulata* in its low tumidity but has more numerous ribs which branch fairly often: it also has coarse growth-lines. More numerous, more often branching ribs also distinguish *M. pinajae* Krumbeck 1923 and *M.* cf. *noetlingii* Krumbeck 1913 from *M. lenticulata*. *M. asymmetrica* Wanner, Knipscheer, and Schenk 1952 and species such as *M. loczyi* described by Kutassy (1934) are distinctly asymmetrical in rib-arrangement. It may be of phylogenetic significance that Arabian and Indian species of *Misolia* (*M. noetlingii*, *M. maniensis*, *M. maniensiformis*, *M. lenticulata*) have fewer, simpler ribs than Indonesian species.



TEXT-FIG. 3. A, *Aequipecten serraticosta* (Bittner), LL306, ×10. B, *Lopha blanfordi* (Lees), LL363, ×3·5. C, *Costatoria omanica* (Diener), LL409, ×10. D, *Pseudolimea ?cumaunica* (Bittner), LL403, ×4. E, *Costatoria ?vestitaeformis* (Krumbeck), LL426, ×3·5. F, *Anodontophora griesbachi* Bittner, LL474, ×3·5.

LAMELLIBRANCHIA

by R. G. S. HUDSON and R. P. S. JEFFERIES

Family NUCULIDAE d'Orbigny 1846

Genus NUCULA Lamarck 1799

Subgenus NUCULOPSIS Girty 1911

?Nuculopsis misolensis (Jaworski)

Plate 2, figs. 15, 19, 20

Nucula sp. nov. Krumbeck 1913, p. 53, pl. 3, figs. 18*a*, *b*.
Nucula misolensis Jaworski 1915, p. 106, pl. 44, figs. 7–13; Wanner and Knipscheer 1951, p. 58, pl. 5, fig. 5.
?Nucula cf. *misolensis* Jaworski. Reed 1927, p. 205.
?Nucula cf. *strigillata* Goldfuss. Lees 1928, p. 634.

Material. LL120, internal cast with tooth lamellae preserved (Pl. 2, figs. 15, 19, 20). *Modiolus* Beds, Sumra Formation.

This specimen agrees very well in shape with Type *B* of *Nucula misolensis* Jaworski (1915, pl. 44, fig. 13, not fig. 12). However, it is much smaller than most of the specimens of this species figured by Jaworski and also smaller than that figured by Wanner and Knipscheer (1951, pl. 5, fig. 5). It is, therefore, probably juvenile, which would explain why it lacks the internal ribs recorded by Wanner and Knipscheer and also, since the number of teeth in a taxodont increases with the age of the shell (Bernard 1896), why the anterior tooth-row has thirteen teeth instead of about twenty.

In his synonymy of *N. misolensis*, Jaworski quoted *N. fritschi* Boettger 1880. Though there is fairly good agreement between *N. misolensis* and the specimen figured by Boettger (1880, pl. 1, figs. 19, 20), later figures of *N. fritschi* (Krumbeck 1914, pl. 16, figs. 16*a–d*, 17) show a strong keel. There is also a strong external resemblance between *N. misolensis* and *N. strigillata* Goldfuss from the Ladinian of the Alps (see, for example, Bittner, 1895, pl. 17, figs. 1–17). The latter species, however, has a keel running forward from the umbo and its anterior dorsal sides are less steeply inclined to the median plane and are clearly visible in lateral view. Wanner and Knipscheer stated that the hinge of *N. misolensis* was not like that of *N. strigillata* since, in the former, the chondrophore slanted forward from the umbo and the anterior tooth row slightly overlapped the posterior, features which were both noticed by Quenstedt (1930) in the Jurassic species *N. hammeri* Defrance.

The resemblance to *N. hammeri* suggests the allocation of *N. misolensis* to *Paleonucula* Quenstedt 1930, of which *N. hammeri* is the type. According to Schenck (1934, p. 36), however, *Paleonucula* is probably only a subgenus of *Nuculopsis* Girty 1911 to which, therefore, the present species is tentatively ascribed.

N. misolensis is the name-fossil of the *Nucula* Marl of the Misol Archipelago and is also known from the Fogi Beds of the west Buru and possibly from the Upper Triassic of Yunnan.

Family MYTILIDAE Fleming

Genus MODIOLUS Lamarck 1799

Modiolus jaworskii Wanner and Knipscheer

Text-fig. 4*a*

Modiola spec. indet. Jaworski 1915, p. 105, pl. 45, fig. 4.
Modiola jaworskii Wanner and Knipscheer 1951, p. 57, pl. 5, figs. 2–4.

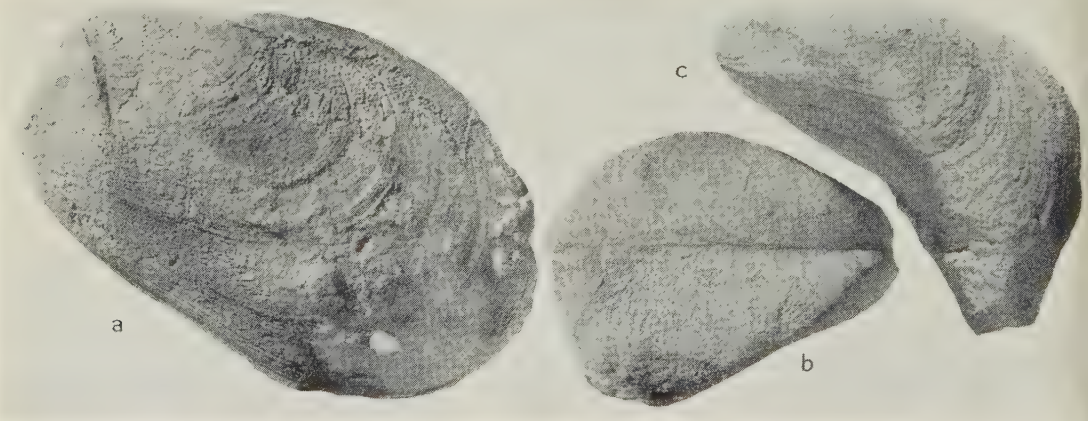
Material. LL126, LL127, LL139–45 (LL140, text-fig. 4*a*), *Lopha* Beds, Sumra Formation. LL128–38, *Modiolus* Beds, Sumra Formation.

The Oman specimens agree very well with published figures of *M. jaworskii* from Indonesia though it is true that the shading in Jaworski's figure (1915, pl. 45, fig. 4) seems to indicate that the sulcus connecting the umbo with the middle of the ventral margin is deeper than in the Oman material. But the sulcus does not show in the growth-lines of the same figure and Jaworski says that the ventral margin is 'ganz geradlinig, vielleicht ganz schwach konkav eingebuchtet'. This would exactly describe the ventral margin of an Oman specimen. Some specimens of *M. jaworskii* figured by Wanner and

Knipscheer show strong concentric sulci. These, however, do not appear to be present in all Indonesian specimens and are occasionally found in specimens from Oman. Consequently they do not justify specific separation.

M. jaworskii grows to a greater size than *M. omanensis* while young specimens can be distinguished from the latter by having a weaker sulcus, straighter ventral margin, longer hinge margin, and greater obliquity. From most other Triassic *Modiolus*, *M. jaworskii* can be separated by its great height in relation to its length. *M. dubius* Healey (1908, p. 55, pl. 8, fig. 11) is very small but probably close to *M. jaworskii*, as also is Bittner's *Myoconcha sp.* (1899, pl. 7, fig. 21). *Modiola sp.* (Krumbeck 1913, p. 49, pl. 3, figs. 9–10) is longer and slimmer than *M. jaworskii* and has a much more concave ventral margin and deeper sulcus.

M. jaworskii is recorded from the *Nucula* Marl of the Misol Archipelago.



TEXT-FIG. 4*a*. *Modiolus jaworskii* Wanner and Knipscheer, left valve, LL140, ×2·5. 4*b* and *c*, *Modiolus speciosus* Merla, left valve, LL146, ×1·5. *c*, Dorsal view looking down commissural plane of left valve. Both from *Lopha* Beds.

Specimens of text-figs. 4–12 (except 10*b*) are from Sumra Formation, Wadi Milaha, Oman. All, except text-fig. 7, were coated with ammonium chloride before photography.

Modiolus speciosus Merla

Text-figs. 4*b*, 4*c*

Mytilus sp. ind. Diener 1908*a*, p. 139, pl. 24, fig. 6.
Modiola speciosa Merla 1933, p. 117, pl. 6, fig. 17.

Material. LL146 (text-figs. 7*b*, 7*c*), LL147–8. *Lopha* and *Modiolus* Beds, Sumra Formation.

Merla rightly compared his new species with *M. paronai* Bittner (1895, p. 48, pl. 5, fig. 19) from the Carnian of Lombardy and with *M. frugi* Healey (1908, p. 54, pl. 8, figs. 8–10) from the Burmese Rhaetian. *M. speciosus*, however, differs from *M. paronai* and most other described Triassic *Modiolus* in its strong carina. It differs from *M. frugi* in having no sharp angle between the hinge-line and posterior margin.

Mytilus sp. ind. (Diener 1908*a*) is clearly a specimen of *Modiolus speciosus*. In considering its generic position it is noteworthy that Diener compared his specimen with *Modiolus minutus* (Goldfuss) from the German Muschelkalk.

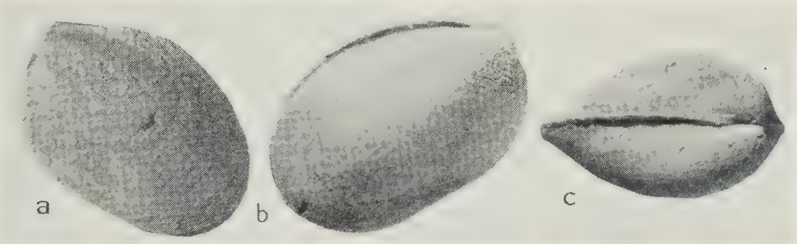
The type specimens of *M. speciosus* Merla came from the Upper Norian of Depsang, Tibet, and the specimen figured by Diener (1908*a*) from the *Megalodon* Limestone of Spiti.

Modiolus omanensis sp. nov.

Text-fig. 5*a–c*

Holotype, LL154 (text-figs. 5*b*, *c*). *Paratype*, LL150–3, LL200 (text-fig. 5*a*). Other specimens, LL155–99, LL201–303, LL305, all from *Modiolus* Beds, Sumra Formation.

Description. Dimensions (LL186): Length 18 mm., height 14 mm., width 8 mm. Outline rounded trigonal or oblong with height only slightly less than length. Hinge-line somewhat convex, grading into anterior and posterior margins. Slightly convex posterior margin grades into slightly concave ventral margin with which it makes an angle of about 10° (in oblong forms) or 20° (in trigonal forms). A weak sulcus runs from the umbo to the slight concavity of the ventral margin. Umbones projecting above hinge, subterminal, somewhat prosogyrous, without an umbonal septum. Shell thin, brownish as preserved, ornamented with weak concentric growth-lines and revealing characteristic radial mytilid structure when slightly weathered.



TEXT-FIG. 5. *Modiolus omanensis* sp. nov. from *Modiolus* Beds. *a*, Left valve of trigonal form, LL200, ×2·5. *b* and *c*, Holotype, oblong form, LL154, ×2·5. *b*, Right valve; *c*, dorsal view.

Comparison. The forms which Healey described (1908) from the Rhaetian of Burma as *Modiola* spp. 1, 2, 3, and 4 are almost certainly conspecific and closely resemble *M. omanensis*. The latter, however, has a less pronounced antero-ventral angle. *M. omanensis* is also superficially like *Datta oscillaris* Healey (1908) but lacks the well-developed posterior wing and the very strange hinge-structure of that species. *M. frugi* Healey (1908) from the Burmese Rhaetian, and *M. salzstettensis* Hohenstein (1913) from the Trochitenkalk of the Black Forest are small, rather trigonal forms like *M. omanensis* but their umbones are more nearly terminal. *M. sodburiensis* Vaughan (1904) from the Rhaetian of South Wales is more orbicular in outline than *M. omanensis* and its height still more nearly equal to its length. Krumbeck's *Modiola sp.* (1914, p. 49, pl. 3, figs. 9, 10) from the Fogi Beds of west Buru is more elongate than *M. omanensis* but similar in general outline. Diener, however (1923, p. 202), thought this species was a *Myoconcha*, a matter which could only be decided by examining its shell structure.

Family PTERIDAE Meek

Genus CASSIANELLA Beyrich 1861

Cassianella cf. *subeuglypha* Krumbeck

COMPARE

Cassianella subeuglypha Krumbeck 1913, p. 143, pl. 1, figs. 16*a–d*.
Cassianella cf. *subeuglypha* Krumbeck. Jaworski 1915, p. 94, pl. 43, figs. 18, 19.

Material. LL149*a*, a single left valve with ventral parts missing. *Modiolus* Beds, Sumra Formation. L52751, coll. Lees, poor internal cast of left valve. Five miles east of Ras al Khaima, Oman.

The Oman specimens are very like *C. subeuglypha* as figured by Krumbeck (1913, pl. 1, figs. 16 *a–d*). His figured specimen, however, seems to have a concave anterior ear and more deeply concave sulci between the radial keels or ribs; it is also somewhat less oblique than the Oman specimens. These differences suggest that the Oman form is possibly a new species.

Other species differ from the Oman specimens as follows: *C. katialotica* Krumbeck from the Norian of Sumatra (Krumbeck, 1914, p. 226, figs. 2–4) has a greater length/height ratio and a posterior keel only weakly developed. *C. verbeeki* Krumbeck 1914 lacks the anterior keel but has a general resemblance in shape. *C.* cf. *subeuglypha* Jaworski (1915, p. 96, pl. 43, figs. 18–19) differs by having a better developed central keel; otherwise it is very close indeed. *C.* nov. sp. aff. *subeuglypha* Krumbeck (1924, p. 248, pl. 186, figs. 16*a–b*) differs in the shape of the anterior ear and by its strong radial ornament.

C. subeuglypha Krumbeck and *C.* cf. *subeuglypha* Jaworski come respectively from the *Athyris* Limestone of Jillu (Misol Archipelago) and from the *Nucula* Marl of Misol.

EXPLANATION OF PLATE 2

All figured specimens are from the Elphinstone Beds, Upper Trias of Wadi Milaha, Jebel Hagab area, near Ras al Khaima, Trucial Oman, Arabia. All were coated with ammonium chloride before photography. Figs. 1–14, 16–18, 21, 23–26, ×1. Figs. 15, 19, 20, 22, ×2.

Figs. 1–4, 8, 9. *Indopecten clignetti asperior* subsp. nov. 1–3, LL321; 4, 8, LL310; 9, LL313. *Modiolus* Beds, Sumra Formation. 1, 4, Left valve; 2, 8, 9, posterior view; 3, right valve. Figs. 1–4 are abraded specimens which, in consequence, resemble '*Pecten*' *margariticostatus* Diener.

Figs. 5–7. *Indopecten amusiiformis* sp. nov., holotype, LL309. 5, Right valve; 6, posterior view; 7, left valve. *Dicerocardium* Limestone, Asfal Formation.

Figs. 10, 11, 14. *?Homomya sublariana* Krumbeck, LL452. 10, Right valve; 11, anterior view; 14, dorsal view. *Lopha* Beds, Sumra Formation.

Figs. 12, 16, 21. *Protocardia rhaetica* (Merian), LL430. 12, Left valve; 16, dorsal view; 21, anterior view. *Modiolus* Beds, Sumra Formation.

Figs. 13, 17. *Megalodon ?hungaricum* Kutassy, LL427*b*. 13, Dorsal view; 17, right valve. Elphinstone Beds (exact horizon not known).

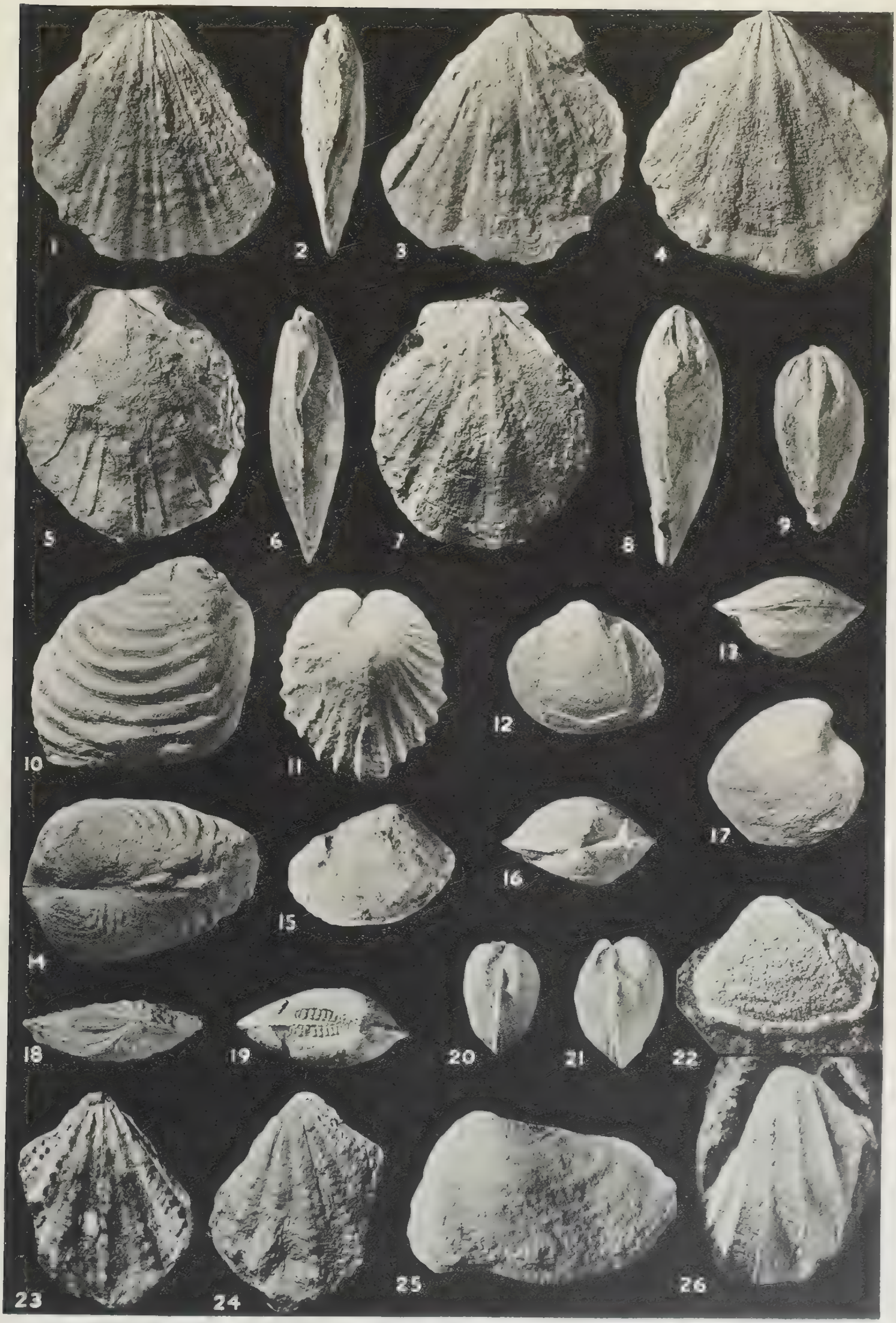
Figs. 15, 19, 20. *Nucula misolensis* Jaworski, LL120. 15, Left valve; 19, dorsal view; 20, posterior view. *Modiolus* Beds, Sumra Formation.

Figs. 18, 23, 24. *Aequipecten serraticosta* (Bittner), LL306. 18, Dorsal view; 23, left valve; 24, right valve. *Lopha* Beds, Sumra Formation.

Fig. 22. *?Megalodon rostratiforme* Krumbeck, LL429, left valve. *Modiolus* Beds, Sumra Formation.

Fig. 25. *Pleuromya himaica* Diener, LL462, left valve. *Modiolus* Beds, Sumra Formation.

Fig. 26. *Myophoria verbeeki mansuyi* Reed, LL422, left valve. *Lopha* Beds, Sumra Formation.



HUDSON AND JEFFERIES, Noric lamellibranchs

Family PECTINIDAE Fleming

Genus AEQUIPECTEN Fischer 1886

Aequipecten serraticosta (Bittner)

Plate 2, figs. 18, 23, 24; text-fig. 3A

Lima serraticosta Bittner 1899, p. 50, pl. 8, figs. 12, 13; ?p. 51, pl. 10, fig. 26.
Lima cf. *serraticosta* Bittner. Diener 1908*a*, pp. 99, 132, pl. 17, fig. 6.
?Indopecten sp. Cox 1935, p. 3, pl. 1, figs. 1*a*, *b*.

Material. LL306 (Pl. 2, figs. 18, 23, 24), LL307–8. *Lopha* Beds, Sumra Formation.

Morphology. Right valve more convex than left. Left valve with eight radial folds, the anterior and posterior pairs being much weaker than those between. All folds, except the most anterior and the most posterior, distinctly angular in section and separated by furrows of same shape and amplitude. Crest of each fold carries a row of tubercles. Whole surface ornamented by close-set, fine, concentric growth-lines, every fourth or fifth growth-line being raised and the free edge characteristically crimped (text-fig. 3A). These crimped growth-lines do not show on a weathered specimen since the crimping affects only the free edge of a raised growth-line and the base is not involved. Shell consists of an outer, transparent, thin, dark-brown layer and an inner, opaque, thick, light-brown layer, the former being thickest over the tubercles. No trace of *Indopecten* structure (see later). Ornament of right valve like that of left but nine radial folds instead of eight. This is due to additional coarse median fold. One valve (?right) much thicker-shelled than the other and provided with strong radial ribs before and behind each radial fold. Internal radial ribs on the thinner valve lie opposite those on the thicker and are less well developed. Ears not seen. Divided from flank in both valves by slightly concave areas perpendicular to the commissure.

Comparison. In specimen LL306 the two most anterior ribs are farther apart than in the first figured specimen of *Lima serraticosta* (Bittner 1899, pl. 8, fig. 12): otherwise there is very good agreement. The Oman specimen also resembles the other specimen figured by Bittner (1899, pl. 8, fig. 13): this, however, is an internal cast so that comparison is difficult. The Oman specimens are less like the specimen figured by Bittner on pl. 10, fig. 26: this has non-tuberculate ribs and comes from a higher horizon than the other two specimens. *Indopecten sp.* from the Triassic of the Attock district (Cox 1935) is probably *A. serraticosta*. Since it did not show *Indopecten* structure it was thought to be a right valve.

Generic allocation. Bittner (1899) and Diener (1908*a*) allocated '*serraticosta*' to *Lima*: this is clearly incorrect since *Lima* is never inequivalve. Subsequently Krumbeck (1924, p. 343) placed it near his new species *Pecten* (*Aequipecten*) *subserraticosta*. The latter has rather sparse *Indopecten* structure on the left valve and for this reason Krumbeck placed it in the '*verbeeki*' group. Consequently, when this group was made the basis for the new genus *Indopecten*, both *serraticosta* and *subserraticosta* Bittner were allocated to that genus (Douglas 1929, p. 633). It seems very likely that the present species is indeed related to *Indopecten subserraticosta* Krumbeck for there is a strong resemblance in the ribbing and the internal ribs are also *Indopecten*-like. There is, however, no true *Indopecten* structure though the outer brown layer is especially thick over the tubercles of the left valve which suggests that these tubercles looked like dark spots when the animal was alive, that is, it had a colour pattern produced in fundamentally the same way as in *Indopecten*. Since '*serraticosta*' is neither a *Lima* nor an *Indopecten* and since it has an inequivalve shell and because of the nature of its ribbing it is here placed in *Aequipecten*.

Distribution. Known from the '*Tropites* Beds' (= *Halorites* and *Proclydonautilus griesbachi* Beds) and possibly from the '*Spiriferina griesbachi*' Beds and *Sagenites* Beds of Painkhanda, the *Juvavites* and *Monotis* Beds and Quartzite Series of Spiti, and from beds referred to Triassic in the Attock district.

Genus INDOPECTEN Douglas 1929

Structural colour-banding. The genus *Indopecten* Douglas (type species: *Pecten clignetti* Krumbeck 1913) is based on Krumbeck's '*verbeeki*' group (1924, p. 343). It includes a number of Upper Triassic Indo-Pacific Pectens which have the left valve somewhat less convex than the right and in which both valves carry five or more weak or strong radial folds and have internal ribs arranged in pairs near the ventral border: the shell structure is also characteristic for both valves consist of an outer translucent dark-brown layer covering an inner opaque light-brown layer, and in the left valve zigzag thickenings of the outer layer let into the outer surface of the inner layer show from outside as a pattern of dark-brown lines within the shell. This structure of zigzag brown lines is in the paper referred to as *Indopecten* structure (Pl. 1, figs. 3, 4).

The genus includes the following species: *Pecten verbeeki* Boettger 1880, *P. microglyptus* Boettger 1880, *P.* (*Variamussium*) *margariticostatus* Diener 1908*a*, *P.* (*Aequipecten*) *clignetti* Krumbeck 1913, *P. misolensis* Jaworski 1915, *P. krumbecki* Jaworski 1915 (= *P. clignetti glabra* Krumbeck 1913), *P. iranicus* Krumbeck 1922 (*nom. nud.*), *P. subserraticosta* Krumbeck 1924, *P.* (*Aequipecten*) *seinaamensis* Krumbeck 1924, *Indopecten palfyi* Kutassy 1935, *?I. transylvanicus* Kutassy 1935, *I. giganteus* Wanner and Knipscheer 1951, *I. clignetti* (Krumbeck) *asperior* subsp. nov., and *I. amusiiformis* sp. nov. *?Lima serraticosta* Bittner 1899, though probably related to *I. subserraticosta*, does not seem to be strictly an *Indopecten* and the same is probably true of *Indopecten sp.* Cox 1935: in neither is *Indopecten* structure known.

Krumbeck (1913, p. 39) hesitantly suggested that *Indopecten* structure served to strengthen the left valve. It seems more likely to have been an expression of colour-banding. This would explain its restriction to the left valve since Pectens always swim or lie with the left valve uppermost so that this valve is usually more brightly coloured than the right. Structures superficially comparable to *Indopecten* structure also occur in recent molluscs, such as the gastropod *Neritina communis* from the Philippines. If this interpretation is correct the presence of *Indopecten* confirms that the Sumra Formation was deposited in photic conditions.

Indopecten structure is by no means confined to *Indopecten*; it also occurs in the following Triassic species of *Entolium*: *Pecten discites* Schlotheim 1820, *P. filosus* Hauer 1857, *P. azzarolae* Stoppani 1861, *P. schlösseri* Wöhrmann 1889, *P.* cf. *subdemissus* Bittner 1895, *P.* (*Syncyclonema*) *quotidianus* Healey 1908, and *P.* (*Entolium*) *decoratiformis* Krumbeck 1924. It does not seem to be known whether *Indopecten* structure is restricted to the left valve in these forms. They are most likely closely related to each other and probably to *Indopecten*, and Jaworski (1915, p. 147) included them in his *clignetti* group together with *Indopecten*. It should be noted that Bittner (1895, p. 165) described *Indopecten* structure as colour-banding in *Entolium* cf. *subdemissum* (Muenster).

Fischer (1925) described three colour varieties of *Pleuronectites laevigatus* (Schlotheim) from the Muschelkalk near Toulon. One of these varieties, *P. laevigatus derognati* (Fischer), shows what is essentially *Indopecten* structure on the left valve only. Presumably this variety is not phylogenetically connected either with *Indopecten* or with the species of *Entolium* listed above: its *Indopecten* structure must be an independent development.

The distribution of Indopecten. Douglas (1929, p. 631) based far-reaching palaeogeographical conclusions on the distribution of many forms supposedly absent from the Himalayas but present in Indonesia and the Middle East. Among such forms he wrongly included *Indopecten* which had already been found in Spiti (Diener 1908*a*) and recorded as *Pecten* aff. *monilifero* (= *I. clignetti*) and as *Pecten* sp. ind. aff. *massalongi* Stoppani (= *I. amusiiformis* sp. nov.). *Pecten* (*Variamussium*) *margariticostatus* is also probably an *Indopecten*, possibly *I. clignetti*.

Arkell (1956, p. 401) has already refuted Douglas's views on the basis of the *Indopecten sp.* recorded by Cox (1935, p. 3, pl. 1, fig. 1) from the Attock district of the Himalayas. As pointed out above, however, Cox's specimen is probably *Aequipecten serraticosta* (Bittner) and hence cannot be used as evidence against the views of Douglas.

Indopecten amusiiformis sp. nov.

Plate 2, figs. 5–7

Pecten sp. ind. aff. *Massalongi* Stoppani. Diener 1908*a*, p. 131, pl. 23, fig. 10.

Holotype, LL309 (Pl. 2, figs. 5–7). *Dicerocardium* Limestone, Asfal Formation.

Description. Shell thin-shelled, right valve slightly more convex than left. Length 32 mm., height 36 mm., thickness 11 mm. Umbones median, projecting slightly above hinge-line; apical angle about 100°. Outline of flank of shell (apart from ears) an almost regular pentagon but angles rounded (except umbo).

Left valve with six weak folds separated by five weak furrows. Near the umbo these folds are stronger than farther away and somewhat angular. The two median folds coincide with rounded obtuse angles in ventral margin. Three median folds near umbo have weak secondary ribs which quickly die out ventrally. *Indopecten* structure present over whole valve. Ears separated from flank by elongate, concave areas, roughly perpendicular to commissural plane. Anterior margin of anterior ear arcuate with distinct byssal sinus. Posterior margin of posterior ear probably sinuous. Near ventral margin internal ribs present before and behind second to fifth radial folds. Internal ribs anterior and posterior to this possibly present but not seen.

Right valve with five radial folds, very weak except near umbo. Folds separated by four furrows that are distinctly angular in section near umbo but much weaker ventrally. Internal ribs present near ventral margin in pairs before and behind each furrow with the addition of a single rib before the anterior radial fold. Ears separated from flank by sharp flexure. Anterior margin of anterior ear with distinct byssal notch. Posterior margin of posterior ear sinuous.

Remarks. The holotype of *I. amusiiformis* clearly belongs to the same species as the specimen from the *Monotis* beds of Spiti described by Diener (1908*a*) as *Pecten* sp. ind. aff. *Massalongi*. This specimen, contrary to Diener's opinion, is a left valve for his figure shows excellent *Indopecten* structure. *I. amusiiformis* is not very similar to *P. massalongi* Stoppani in which the internal ribs are much more numerous.

The new species differs from *I. clignetti asperior* (subsp. nov.) and *I. clignetti clignetti* (Krumbeck) in being more nearly equivalve, in having weaker secondary ribs, a thinner shell, and no crenulations on the radial folds of either valve. It differs from *I. krumbecki* (Jaworski) in having much weaker radial folds and from *I. verbeeki* (Boettger), *I. microglyptus* (Boettger), and *I. misolensis* (Jaworski) in lacking crenulations on both valves. *I. glabra* Douglas (not Krumbeck 1913) is a much bigger species, very inequivalve and with strong secondary ribs. *Entolium* cf. *subdemissum* Muenst. (Diener 1908*a*, p. 138, pl. 24, fig. 12) at first sight closely resembles the present species but shows no sign of radial folds or *Indopecten* structure. Of the species just mentioned the one closest to *I. amusiiformis* is probably *I. microglyptus* (Boettger).

Indopecten clignetti asperior subsp. nov.

Plate 1, figs. 1–3; Plate 2, figs. 1–4, 8, 9

?*Pecten* (*Variamussium*) *margariticostatus* Diener 1908*a*, pp. 97, 131, pl. 18, figs. 1–3.

?*Pecten* aff. *monilifero* Muenst. Diener 1908*a*, pp. 98, 131, pl. 13, fig. 4, pl. 23, figs. 11–13.

Pecten (*Aequipecten*) *clignetti* Krumbeck (*pars*) 1913, p. 41; Krumbeck (*pars*) 1923, p. 345, pl. 193, fig. 9.

Chlamys (*Aequipecten*) *clignetti* G. Boehm *emend.* Krumbeck. Lees 1928, p. 636, pl. 44, fig. 3.

Holotype, LL314, right valve (Pl. 1, fig. 1). *Paratype*, LL315, both valves (Pl. 1, fig. 2). Other specimens, LL310 (Pl. 2, fig. 9), LL311, 312, LL313 (Pl. 2, figs. 4, 8), LL316–20, LL321 (Pl. 1, fig. 3; Pl. 2, figs. 1–3), LL322–4. LL310–17, LL319–21 from *Modiolus* Beds; LL318, LL322–4 from *Lopha* Beds. All from Sumra Formation.

Description. Shell thick-shelled, inequivalve; both valves convex but right more convex than left. Shell nearly equilateral but umbones slightly anterior. Umbones not prominent, apical angle about 90°. Left valve with six narrow radial folds separated by five broad furrows. Anterior and posterior folds much weaker than the others. The three median furrows each carry two radial secondary ribs. No secondary ribs in the anterior furrow. The posterior furrow bears two secondary ribs near the umbo of which the more posterior is much the stronger and changes ventrally into a sharp radial geniculation. All six folds carry a single row of crenulations which tend to die out ventrally but persist longer on the median four folds than on the anterior or posterior folds. The secondary ribs and the posterior geniculation also often die out ventrally. The left valve has *Indopecten* structure. Before and behind the four median folds the brown lines are curved divaricate. Between these two areas the lines are zigzag with the bisectors of the angles of the zigzag radiating from the umbo.

Right valve with five primary radial folds separated by four radial furrows narrower than the folds. The anterior and posterior folds are much weaker than the others. Each fold carries rows of tubercles; there are one to two rows on the anterior and posterior folds and usually three on the others, and the tubercles are concentrically paired or tripled on each fold. Furrows without secondary ribs.

In both valves concentric growth-lines are convex distally in the furrows, convex proximally over the primary folds. Inside both valves, except near the umbo, there are radial internal ribs. In the left valve, one internal rib lies beneath the posterior radial fold, and internal ribs lie just before and behind the second to fourth radial folds. There is no internal rib beneath the anterior radial fold. In the right valve there is an internal rib opposite every internal rib of the left valve. Ears like portion of cylinder with horizontal axis (compare those of *Pecten maximus* (L.)). Ears of left valve concave, separated from flank by areas roughly perpendicular to plane of commissure; ears of right valve convex, separated from flank by sharp flexures. Left anterior ear with arcuate anterior margin; right anterior ear with strong byssal notch. Posterior border of posterior ear sinuous.

Remarks. I. clignetti asperior differs from *I. clignetti clignetti* (Krumbeck 1913, p. 36, pl. 2, figs. 1–8, pl. 4, fig. 29) by having three rows of tubercles on the third rib of the right valve (and sometimes on second and fourth ribs also) instead of only two. This difference, however, does not demand full specific separation since the form with three rows of tubercles is known in Indonesia (Krumbeck 1913, p. 41; 1923, pl. 193, fig. 9) within the *I. clignetti clignetti* plexus. The Oman form is therefore considered to be a geographical variant of the Indonesian species. The name *asperior* (= rougher) indicates that the tubercles are more abundant than in *I. clignetti clignetti.*

The form which Diener (1908*a*) figured and described as *Pecten* aff. *monilifero* is clearly specifically identical with *I. clignetti.* Which subspecies it belongs to, however, cannot be decided until the right valve is known. It is also possible that *Pecten margariticostatus* Diener 1908*a* is based on abraded specimens of *I. clignetti.* Certainly abraded specimens of *I. clignetti asperior* (Pl. 2, figs. 1–4) from Oman have a strong resemblance to one of the figures of *P. margariticostatus* (Diener 1908*a*, pl. 18, fig. 1). If *P. margariticostatus* is identical with *I. clignetti* the latter is a junior synonym. The matter, however, can only be decided by examination of the type specimens of the former. Pending such examination it is better to retain the specific name *clignetti. I. seinaamensis* (Krumbeck 1923, p. 344, pl. 193, figs. 10–12) differs from *I. clignetti asperior* by having more than five tuberculate folds on the right valve, by having up to five rows of tubercles on the median fold of the right valve, and by the absence of distal weakening in the ornament.

I. clignetti asperior probably spent most of its life with the commissure about level with the sea-bed and the right valve buried. The radial folds of the right valve would help to hold the shell in place: a suggested explanation for why they are so much stronger than those of the left valve.

Distribution. I. clignetti asperior is known from the Fogi Beds and *Athyris* Limestone of the Misol Archipelago. *I. margariticostatus* (Diener) and '*Pecten* aff. *monilifero*', which may be identical with *I. clignetti asperior*, are known from the *Juvavites* Beds, *Monotis* Beds, and Quartzite Series of Spiti.

DIMYIDAE Dall

Genus *Dimyodon* Munier-Chalmas 1886

Dimyodon cf. *subrichtofeni* Krumbeck

COMPARE

Dimyodon subrichtofeni Krumbeck 1924, p. 347, pl. 193, fig. 18; ?Reed 1927, p. 221.
Dimyopsis sp. Lees 1928, p. 637.

Material. LL325, LL326 (attached to *Spiriferina abichi* (Dav.) *s.l.*), BB20491, BB20502, BB20503 from *Spiriferina* Limestone, Asfal Formation. LL327 (attached to shell fragment), *Lopha* Bed, Sumra Formation. LL427*a* attached to *Megalodon hungaricum* LL427*b*; exact horizon in Elphinstone Beds not known. LL51449, thirteen specimens attached to holotype of *Myophoria gigantea* Lees (= *M. verbeeki mansuyi* Reed).

The genus *Dimyopsis* (Bittner 1895, p. 219), in which Lees placed his specimens of this species, differs from *Dimyodon* in having no teeth. This distinction, however, is very difficult in practice since the umbo region of these forms is thin and has usually been damaged. Thus of the seventeen specimens examined in the present investigation only two show the two small diverging teeth of the right valve characteristic of *Dimyodon*: the differences between these specimens and the others are certainly preservational and have no taxonomic value whatever.

None of the specimens seen are well enough preserved to prove that they belong to *Dimyodon subrichtofeni* Krumbeck rather than to *D. richtofeni* Bittner (1895, p. 217). They have been compared with the former species only because an Indonesian relationship seems more likely than a European one. The specimens described as *Dimyopsis* cf. *intusstriata* Emmrich from the Fogi Beds and *Athyris* Limestone of the Misol Archipelago (Krumbeck 1913, p. 44) and as *Dimyodon richtofeni* Bittner from the *Nucula* Marl of Misol (Jaworski 1915, p. 103) are probably specifically identical with the Oman specimens. The left valve of *D. subrichtofeni* has not previously been described. It is thin, moderately convex, and with faint radial striae. Some of the specimens of '*Myophoria gigantea*' show both valves in apposition.

The type of *D. subrichtofeni* is from the Carnian of Timor. Comparable forms are known from the Norian of the Misol Archipelago and the Upper Triassic of Yunnan.

Family OSTREIDAE Fleming

Genus LOPHA Bolten 1798

Lopha blanfordi (Lees)

Text-figs. 3B, 8*d*, *e*

Exogyra Stoliczka *in* Blanford 1872, p. 76.
Exogyra sp. ind. aff. *conica* Diener 1908*b*, p. 159, pl. 36, fig. 4 (not *Chama conica* J. Sowerby 1813).
Ostrea (*?Exogyra*) *Blanfordi* Lees 1928, p. 634, pl. 44, figs. 2*a*–*b*.
Alectryonia parasitica Saurin 1941, p. 7, pl. 1, fig. 38, pl. 2, figs. 2–5 (not Krumbeck 1913).
Probably *Alectryonia* aff. *montis caprilis* Saurin 1941, p. 7, pl. 1, figs. 39–41, pl. 2, fig. 1 (not Klipstein 1843).

Material. LL328–42 (LL335, fig. 8*d*, *e*), LL344–61, LL365, LL366. *Lopha* Beds, Sumra Formation. LL343, LL362–4. *Modiolus* Beds, Sumra Formation.

Morphology. Internal features seen in specimen LL363. Anterior external ligament trace reduced or absent. Internal ligament trace not a distinct groove but marked by series of growth-lines slightly convex distally. Adductor scar just ventral to umbo. No pseudo-taxodont dentition, no internal marginal crenulations; left valve not thicker shelled than right. External folds only reflected internally near the shell margins.

Remarks. The present species has the strong radial ribs and serrated commissure of *Lopha* (= *Alectryonia*) and the involute umbones of *Exogyra*. In fact it could almost equally well be placed in either genus. It is here referred to *Lopha* because the nature of the ribbing is somewhat easier to see than the nature of the umbo. Krumbeck would probably have approved this ascription since he called the most nearly related form *Alectryonia parasitica* (1913, p. 47, pl. 3, figs. 4–8).

L. blanfordi differs from *A. parasitica* Krumbeck in having somewhat stronger ribs which begin at the attachment area instead of more distally. The weaker ribbing of *A. parasitica* is probably not due to the nature of the attachment since the attachment area varies greatly in size in the published figures (Krumbeck, 1913, pl. 3, figs. 4–8) and the ribbing is not affected. *Ostrea* (*Alectryonia*) cf. *parasitica* Krumbeck (1923, p. 206, pl. 13, figs. 2–4) is still more like *L. blanfordi* but the ribs seem wider and do not always start at the attachment area. The form which Saurin (1941, p. 7) called *A. parasitica* is more like *L. blanfordi* since it is ribbed over the whole free surface. It also seems likely that *A.* aff. *montiscaprilis* of Saurin is of the same species as his *A. parasitica* and should also be united with *L. blanfordi*. Saurin described the form of his specimens as not *recourbée* without describing the curvature of the umbones which in true *montiscaprilis* are non-involute (Bittner 1912, pl. 6, fig. 17). In his synonymy of *L. blanfordi* Lees (1928, p. 634) rather doubtfully quoted *A.* cf. *haidingeriana* of Healey (1908, p. 37, pl. 5, figs. 18–19). This seems to have been a mistake, however, for Healey stated of her specimens that though the umbo was twisted in certain examples, in most it remained straight (p. 37). The umbo is also straight in the form identified by Fleming (1953, p. 276) as *L.* cf. *haidingeriana* (Emmrich) from the Rhaetian of New Zealand. Krumbeck (1913, p. 48) mentioned the occurrence of oysters with involute umbones in the Rhaetian of Hungary. These forms must be closely related to *L. parasitica* and *L. blanfordi*.

L. blanfordi is recorded from the Elphinstone Beds of the Elphinstone Inlet and of the area 5 miles east of Ras al Khaima, and from the Upper Triassic of Hoa Huynh, south Annam.

Family LIMIDAE d'Orbigny

Genus PSEUDOLIMEA Douglas and Arkell 1932

Pseudolimea ?cumaunica (Bittner)

Plate 1, fig. 4; text-figs. 3D, 6*a*, *b*

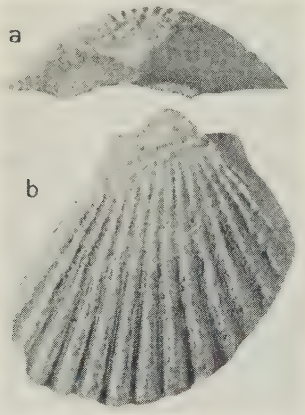
Lima cumaunica Bittner 1899, p. 59, pl. 10, fig. 25. 1908*a ?Lima cumaunica* Bittner, p. 137, pl. 24, figs. 10, 11.

Lima subcumaunica Lees 1928, p. 636; not Jaworski 1915, p. 96, pl. 43, figs. 20, 21; not *Lima* (*Radula*) *subcumaunica* Krumbeck 1913, p. 34, pl. 1, figs. 19, 20.

Material. LL368, LL369 (text-fig. 6*a*, *b*), LL370–4, LL375 (Pl. 1, fig. 4), LL376–98. *Modiolus* Beds, Sumra Formation. LL401–3, Sumra Formation (exact horizon not known). LL406 *Spiriferina* Bed, Asfal Formation.

Morphology. Flank with about fifteen strong primary ribs having flat sides and rounded apices. Anterior flank ribs sometimes strongly crenulate distally. Primary flank ribs separated by furrows which are rounded and equal to the ribs in width near umbo (up to a shell length of about 10 mm.) but wider than the ribs and flat-bottomed away from umbo. The rounded parts of the furrows near the umbo carry a distinct secondary rib. Surface covered with numerous regularly spaced growth-lines which are weak on lunule and escutcheon but strong and raised on the flank, not only in the furrows but also over the main ribs when the specimen has not been abraded. The raised growth-lines are interrupted by the secondary ribs and crossed by numerous radial striae weaker than the growth-lines. The growth-lines are convex away from the umbo over the flank ribs and in general convex towards the umbo in the furrows. Where they touch the secondary ribs, however, they form an obtuse angle pointing away from the umbo. This obtuse angle is also present in the parts of the shell farther from the umbo where secondary ribs have disappeared.

Radial ribs usually absent on lunule and escutcheon except on the parts nearest the flank. Ears subequal. Hinge-line with distinct triangular internal ligament-trace and about two small pseudo-taxodont teeth on each side near the cardinal extremities (see text-fig. 3D).



TEXT-FIG. 6. *Pseudolimea ?cumaunica* (Bittner), LL369, ×5·5, from *Modiolus* Beds. *a*, Dorsal view of left valve; *b*, left valve.

Remarks. Lima cumaunica Bittner is referred to *Pseudolimea* Douglas and Arkell 1932 because of its small size and the presence of strong flat-sided ribs and secondary ribs. There is some disagreement about the hinge of *Pseudolimea.* Arkell (1932, text-figs. 20, 21) figured two *Pseudolimea* hinges, both of them edentulous, but Cox (1944) has pointed out that pseudo-taxodont teeth do sometimes occur in the genus. The nature of the hinge, therefore, does not exclude *L. cumaunica* from *Pseudolimea.*

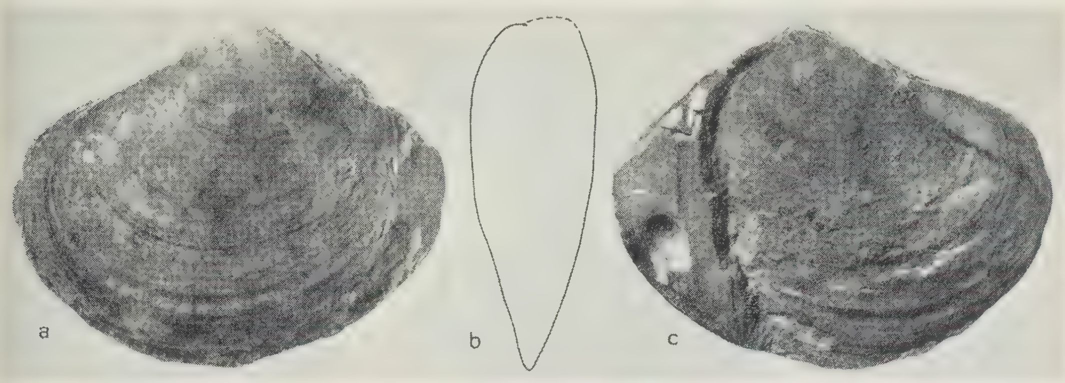
The Oman specimens tentatively referred to *P. cumaunica* agree with Bittner's and Diener's figures of this species in size, outline, number of flank ribs, the presence of secondary ribs (see Diener 1908*a*, pl. 24, fig. 8), and, with a few exceptions, the general lack of radial ribs on most of the lunule and escutcheon (Bittner 1899, p. 59). The horizon is also similar since the species is known in the Himalayas from the *Megalodon* Limestone and the *Spiriferina griesbachi* Bed. The Oman material, however, has very prominent growth-lines, whereas Bittner described the growth-lines of his specimens as scarcely perceptible. He had, however, only two valves and these may have been abraded. For this reason it seems better tentatively to identify the Oman material with Bittner's species than to create a new one.

Lees identified the shells in his collection as *Lima subcumaunica* Krumbeck. The latter is certainly closely related to *L. cumaunica* and has been much better described (Krumbeck 1913, p. 34; Jaworski 1915, p. 96). It differs from the Oman specimens by being more oblique (the angle between the hinge-line and the greatest diameter being about 55° instead of 65°), by normally having abundant radial ribs on lunule and escutcheon, and by having the fine radial lines as strong as the growth-lines instead of being much weaker (Krumbeck 1913, pl. 1, fig. 19*b*; Jaworski 1915, pl. 43, fig. 21*a*). With the possible exception of the last, all these features also distinguish *L. subcumaunica* from the Himalayan *L. cumaunica.*

A number of other *Pseudolimea* from the Himalayas deserve mention. *Lima sp.* (Bittner 1899, p. 50, pl. 7, fig. 20) from the *Halobia comata* Beds is more orbicular in outline than *L. cumaunica*. *Lima sp.* (Bittner 1899, p. 50, pl. 8, fig. 11) is rather close to *L. cumaunica* but too badly preserved for detailed comparison: *Lima* sp. ind. aff. *cumaunica* (Diener 1908*a*, p. 132, pl. 23, fig. 14) may possibly be identical with *L. cumaunica*.

Five of the specimens of *P. ?cumaunica* from Oman are double-valved. Two of these, LL395 and LL397, give the impression, from the way they are crushed, that they were buried with the commissure roughly vertical. This suggests that in life *P. ?cumaunica* adopted the same position as modern *Lima* with the antero-dorsal margin resting on the sea-bed. This is the more likely in view of the somewhat excavated lunule of the species which would make a very firm base. A similar mode of preservation with the animal resting on the lunule also occurs in *L. lineata* Schlotheim from the German Wellenkalk. The other double valved specimens, which from their mode of crushing were probably buried with commissure horizontal, were probably rolled over by current action after death.

P. cumaunica is known from the *Spiriferina griesbachi* Beds of the Painkhanda and the *Megalodon* Limestone of Spiti. The closely related *P. subcumaunica* is from the Fogi Beds of Buru and the *Nucula* Marl of Misol.



TEXT-FIG. 7. *Plagiostoma nudum* (Parona), LL404, ×0·9, from *Lopha* Beds. *a*, Left valve showing concentric colour bands; *b*, outline of anterior view; *c*, right valve showing radial and concentric colour bands (*a* and *c*, coated with oil).

Genus PLAGIOSTOMA Sowerby 1814

Plagiostoma nudum (Parona)

Text-figs. 7*a–c*

Lima (*Plagiostoma*) *nuda* Parona 1889, p. 83, pl. 4, fig. 5; Wöhrmann 1893, p. 652.
Lima (*Plagiostoma*) *mysica* Bittner 1891, p. 109, pl. 2, fig. 1.

Material. LL404 (text-fig. 7*a–c*). *Lopha* Beds, Sumra Formation.

Remarks. The surface of the unweathered shell is completely smooth except for growth-lines. These are fine over most of the shell but coarse in the lunule and on the anterior ear. Weathering reveals a fine radial shell-structure. The one specimen collected shows clear concentric colour-bands over the whole shell, and radial colour-bands on the anterior dorsal part of the right valve. This colour banding, like that of *Indopecten*, strongly suggests that the Sumra Formation was laid down in the photic zone of the sea (see above).

In outline, size, and total lack of radial ornament, the Oman specimen agrees very well with the type specimens (Parona 1889) which came from the Carnian of Lombardy. The internal cast which Reed (1927, p. 229, pl. 18, fig. 31) recorded as *Lima* (*Plagiostoma*) cf. *nuda* shows rather strong concentric folds and hence is probably not very close to the true *L. nuda*. *L.* (*P.*) *mysica* Bittner from the Upper Trias of Balia in Anatolia does not seem to differ essentially from *P. nudum*. *L.* (*P.*) *sp.* (Krumbeck 1913, p. 33, pl. 1, fig. 17) is probably closely related to the Oman specimen but shows weak radial ornament.

Plagiostoma subvaloniense Krumbeck

Plagiostoma subvaloniense Krumbeck 1923, p. 202, pl. 12, figs. 17–19.
Lima (*Plagiostoma*) *subvaloniensis* Krumbeck. Lees 1928, p. 637.

Material. L52751, Lees coll. (a poor right valve). Elphinstone Beds, 5 miles east of Ras al Khaima. LL491, *Misolia* Limestone.

Remarks. Though badly preserved, the Oman specimens agree with the type specimens (Krumbeck 1923, pl. 12, figs. 17–19) in every ascertainable particular. Krumbeck's figured specimens vary considerably in height/length ratio and the Oman specimens correspond to the taller form (Krumbeck 1923, pl. 12, fig. 17*a*). Krumbeck was wrong to describe the internal cast of this species as smooth: in his figures and on the larger Oman specimen (L52751) the internal cast clearly reflects the external radial ribs. The ribs of the present species are broader and less numerous than those of *P. praecursor* (Quenstedt) or *P. valoniense* (Defrance) which are probably its closest relatives.

The types of *P. subvaloniense* are from the Norian Kanike Beds of Ceram.

Family MYOPHORIIDAE

Genus COSTATORIA Waagen 1907

Costatoria omanica (Diener)

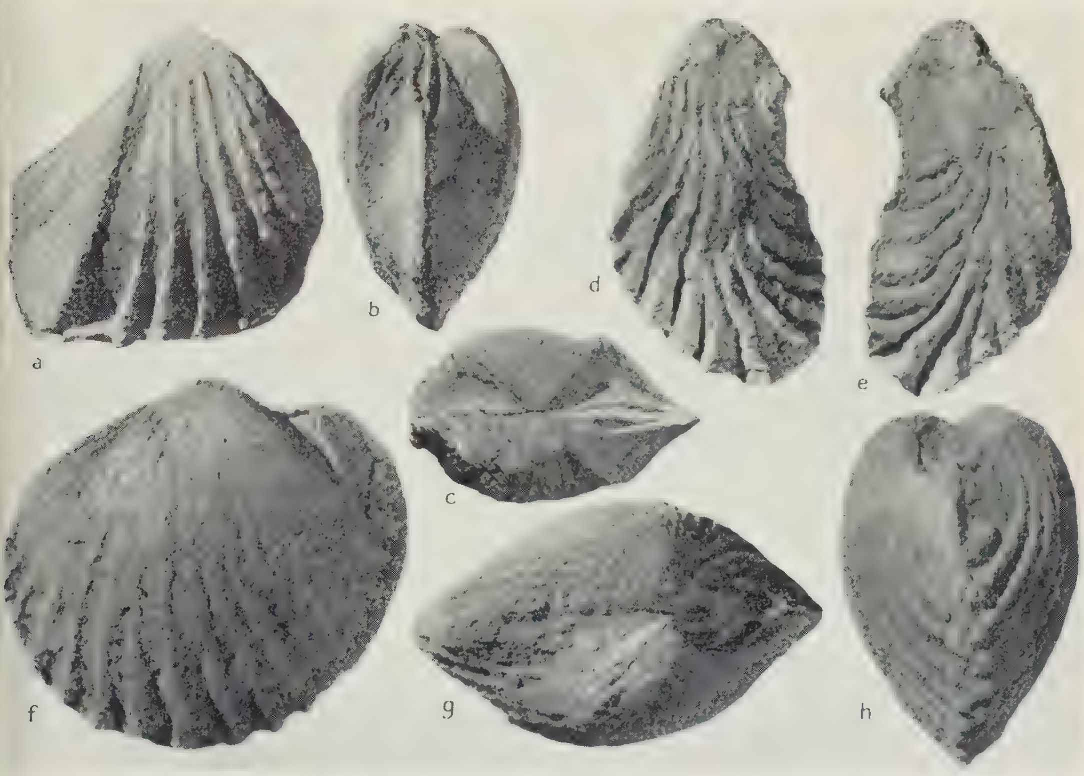
Text-figs. 3C, 8*a–c*

Myophoria aff. *chenopus* Laube. Stoliczka *in* Blanford 1872, p. 76.
Myophoria omanica Diener 1908*b*, p. 156, pl. 24, figs. 1–3; Lees 1928, p. 635.

Material. LL405–6, *Lopha* Beds, Sumra Formation. LL407 (juv.), LL408–21 (LL410, text-figs. 8*a–c*), *Modiolus* Beds, Sumra Formation.

Morphology. Shell equivalve, umbones slightly prosogyrous. Ornament the same in both valves. On flank are about eight radial ribs (not counting marginal carina), narrower than the intercostal furrows and strongly crenulate, the crenulations being elongated concentrically. Siphonal area radially concave, divided at about two-thirds of its height above the base by radial groove, and separated from escutcheon by crenulate external carina. Lunule somewhat sunken, smooth except for growth-lines. Hinge of left valve (text-fig. 3C) seen in one juvenile specimen (LL407). 2*a* strong, not bifid, ventral border convex; 4*a* fairly strong, narrow, as long as 2*a*, with fine striae perpendicular to commissure on posterior face; 4*b* weak, marginal. Socket for 3*a* (of right valve) much deeper than socket for 3*b*. The whole supported on a cardinal plate.

Remarks. The hinge of this species is undoubtedly Myophoriid rather than Trigoniid and the species must be referred to *Costatoria* (Waagen 1907) because of its strong radial ribs. Striae may have been present on other parts of the hinges besides the posterior face of 4*a*. Three European Carnian species closely resemble *C. omanica* externally. *Myorphia inaequicostata* Klipstein (see Bittner 1895, p. 94, figs. 1–14) has the flank ribs in two groups, the anterior ones being closer together than the posterior. *M. chenopus* Laube is still more like *C. omanica* but is longer relative to its height. *M. whateleyae* Buch has weaker and sparser ribs.



TEXT-FIGS. 8*a–c*. *Costatoria omanica* (Diener), LL410, ×1·4, *Modiolus* Beds. *a*, Right valve; *b*, posterior view; *c*, dorsal view. 8*d* and *e*, *Lopha blanfordi* (Lees), LL135, ×1·4, *Lopha* Beds. *d*, Left valve; *e*, right valve. 8*f–h*, *Palaeocardita buruca* (Krumbeck), LL451, ×2·3, *Modiolus* Beds. *f*, Right valve showing impression of myophorial buttress behind anterior adductor; *g*, dorsal view; *h*, anterior view.

The types of *Costatoria omanica* are from the Elphinstone Beds of the Elphinstone Inlet. The species was also recorded by Lees (1928) from 5 miles east of Ras al Khaima.

Costatoria ?vestitaeformis (Krumbeck)

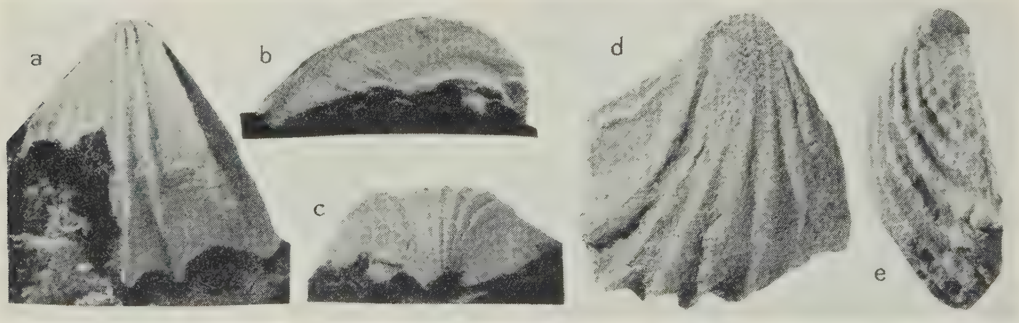
Text-figs. 3E, 9*a–e*

?Myophoria vestitaeformis Krumbeck 1923, p. 210 (nom. nov. for. *M. vestita subvestita* Jaworski 1915, p. 112, pl. 44, figs. 20, 21*a*, *b*, *c*; not *M. subvestita* Krumbeck 1913).

Material. LL423, LL424 (small left valve, text-fig. 9*d*, *e*) LL425 (large damaged right valve, text-figs. 9*a–c*), *Lopha* Beds, Sumra Formation. LL426 (small right valve), *Modiolus* Beds, Sumra Formation.

Morphology. Shell probably slightly inequivalve with left valve more convex than right (see Jaworski 1915, pl. 44, figs. 21*b*, *c*). Ornament the same on both valves. Seven to nine prominent angular radial ribs on flank between lunule and marginal carina. These flank-ribs are steep-sided with weak, radially elongate crenulations. Anterior flank-ribs crossed by weak oblique ribs which form elongate crenulations at the intersections. Lunule smooth. Hinge of right valve with two elongate narrow subequal cardinals (3*a* and 3*b*), the anterior face of the posterior cardinal (3*b*) being coarsely grooved. Striations or grooves may be present also in other parts of the hinge but could not be proved on the specimen examined (LL426).

Remarks. *Myophoria vestitaeformis* Krumbeck (1923, p. 210) was a new name for the form which Jaworski (1915) called *Myophoria vestita subvestita* (not *Myophoria subvestita* Krumbeck 1913). Krumbeck summarized the differences from *M. subvestita* as follows: *M. vestita subvestita* Jaworski obviously differs from *M. subvestita* by being slightly inequivalve (the left valve is higher and thicker than the right), by the characteristic wing-like extension of the upper part of the area, by the absence of an areal rib, and by being less convex. The most important of these distinctions is the alate extension of the area. The slightly inequivalve nature of *M. vestitaeformis*, which Krumbeck insisted on, is clear from Jaworski's figures (1915, figs. 21*b*, 21*c*) though it disagrees with his description (1915, p. 112). The principal reasons for identifying the Oman material with *M. vestitaeformis* are the anterior ornament (oblique ribs surrounding a smooth lunule), the general outline, and the alate extension of the area. The identification is not certain, however, since the hinge is unknown in Indonesia, and double-valved forms, which would show whether the shell was inequivalve, are not known from Oman.



TEXT-FIG. 9. *Costatoria ?vestitaeformis* (Krumbeck), ×2·5, *Lopha* Beds, *a–c*, LL425. *a*, Lateral view of left valve; *b*, posterior view of left valve; *c*, dorsal view of left valve. *d* and *e*, LL423, juvenile specimen. *d*, Lateral view of right valve (anticarinal sulcus has been reduced in width by crushing); *e*, right valve showing ornamentation of lunule.

The hinge of the Oman material is definitely Myophoriid for, though the teeth are in places coarsely grooved, the anterior right cardinal (3*a*) is too narrow for a Trigoniid. The hinge is very like that of *M. subvestita* Krumbeck (1913, pl. 4, fig. 1*a*). In view of the hinge and the strong, unequally spaced, radial ribs, *M. subvestita*, *M. ?vestitaeformis*, and probably *M. vestitaeformis* should be placed in *Costatoria* Waagen 1907. *M. seranensis* Krumbeck 1923 is like *M. vestitaeformis* in anterior ornament and general outline (though without the alate area). Its hinge, however, is Trigoniid with 3*a* wide and triangular. The species should therefore be placed in *Myophorigonia* Cox 1952.

Apart from Oman, *Costatoria vestitaeformis* (Krumbeck) is known to the authors only from the *Nucula* Marl of Misol.

Genus MYOPHORIA Bronn 1835

Myophoria verbeeki (Boettger) *mansuyi* Reed

Plate 2, fig. 26

Myophoria subvestita Krumbeck *Mansuyi* Reed 1927, p. 215, pl. 18, figs. 12–14.
Myophoria verbeeki (Boettger) *curta* Reed 1927, p. 216, pl. 18, figs. 15–17.
Myophoria cf. *napengensis* Healey. Reed 1927, p. 217, pl. 18, fig. 26 (not *Myophoria napengensis* Healey 1908).
Myophoria gigantea Lees 1928, p. 635, pl. 44, figs. 1*a*, *b*.
?*Myophoria verbeeki* (Boettger). Douglas 1929, p. 636; Robinson 1937.

Material. L51449 (holotype of *Myophoria gigantea* Lees 1928, p. 635, pl. 44, figs. 1*a*, *b*) from Elphinstone Beds, 5 miles east of Ras al Khaima. LL422 (Pl. 2, fig. 26) from *Lopha* Beds, Sumra Formation.

Morphology. Ornament of both valves the same. The flank bears six strong, regularly spaced, radial ribs with concentrically elongate crenulations. Lunule anterior to anterior flank rib is flat, smooth except for weak growth-lines, and perpendicular to commissural plane.

Remarks. In 1927 Reed described a number of *Myophoria* from a single bed and locality in Yunnan and referred them to *M. subvestita* Krumbeck *Mansuyi* Reed, *M. verbeeki* (Boettger) *curta* Reed, and *M.* cf. *napengensis* Healey. In the opinion of the authors, all the specimens figured belong to the same form and the question arises as to their valid name. With one exception (pl. 18, fig. 17) all the figures are of internal casts. The exception, which Reed called *M. verbeeki curta*, has the same ornament as *M. verbeeki* (Boettger) from Sumatra (see Krumbeck 1914, p. 249, pl. 17, figs. 8–11) in that it has a non-crenulate marginal keel and wide-spaced, crenulate flank ribs but differs from it in having the posterior margin vertical instead of sloping. It can therefore be justifiably considered a subspecies of *M. verbeeki* (Boettger). Reed's reason for allocating his subspecies *mansuyi* to *M. subvestita* Krumbeck was the smoothness of its ribs—a feature of the internal cast and of no diagnostic value: otherwise it is much closer to *M. verbeeki* than to *M. subvestita*. *M. subvestita mansuyi* (1927, p. 215) has page priority over *M. verbeeki curta* (1927, p. 216). The various forms are therefore renamed *M. verbeeki mansuyi* Reed.

As its author recognized (1928, p. 635), *M. gigantea* Lees is very like *M. verbeeki* (Boettger) but differs in outline since the posterior margin is vertical instead of sloping, a feature characteristic of the *Myophoria* recorded by Reed (1927) from Yunnan and renamed above. There seems no reason therefore why *M. gigantea* should be separated from *M. verbeeki mansuyi*. Lees (1928, p. 635) stated that *M. gigantea* was larger than *M. verbeeki* but there is little difference in size between his only specimen and Krumbeck's largest figured specimen (1914, pl. 17, fig. 10). Examination of the holotype shows that *M. gigantea* is not, as suggested by Lees (1928, p. 635), slightly inequivalve, the structure which suggests this being due to slight crushing.

The unfigured records of *M. verbeeki* in Douglas 1929 and Robinson 1937 should be accepted with reserve. Since they occur in Persia and Armenia the specimens referred to may be *M. verbeeki mansuyi* rather than *M. verbeeki verbeeki* which is only known in Indonesia.

The hinges of the present subspecies and of *M. verbeeki verbeeki* are not known, and may be Trigoniid or Myophoriid. If Trigoniid the species would belong to *Minetrigonia* Kobayashi and Katayama 1938: if Myophoriid to *Costatoria* Waagen 1907. Pending more evidence it seems best to leave it in *Myophoria s.l.*

M. verbeeki mansuyi is thus known from the Upper Triassic of Yunnan and probably from the Norian of Armenia and Persia. *M. verbeeki verbeeki* is known from the Norian Padang Beds of Sumatra.

Family CARDITIDAE

Genus PALAEOCARDITA Conrad 1867

Palaeocardita buruca (Krumbeck)

Text-figs. 8*f–h*

Venericardia buruca Boehm 1906, *nom. nud.* p. 400.
Cardita buruca Krumbeck 1913, p. 60, pl. 4, figs. 6–13.
Palaeocardita globiformis Boettger. Jaworski 1915, p. 115, pl. 45, figs. 1, 2 (not *Cardita globiformis* Boettger 1880).
Palaeocardita buruca Krumbeck 1924, p. 248, pl. 19, figs. 28, 29; Douglas 1929, p. 637.

Material. LL450, LL451 (text-figs. 8*f–h*). The former from the *Lopha* Beds, the latter from the *Modiolus* Beds, Sumra Formation.

Jaworski (1915, p. 115) seems to have been wrong to unite *P. globiformis* Boettger with *P. buruca* Krumbeck, for the latter is less quadrate, less elongate, and has less anterior umbones. Furthermore, nothing is yet known about the lunule or the hinge of *P. globiformis* (see Krumbeck 1924, p. 249) and the asymmetric lunule of *P. buruca* is the most striking feature of the species. The Oman specimens agree exactly in appearance with *P. buruca* as figured by Krumbeck from Buru (1913) and Timor (1924) and the number of ribs (about 23) is within the range (20–30) that Krumbeck (1924, p. 249) quoted for typical Buru specimens of *P. buruca*. It seems doubtful if *P. buruca* var. *misolensis* Krumbeck (= *P. globiformis* Boettger of Jaworski 1915) and *P. buruca* var. *seranensis* Krumbeck 1923 are really distinct from typical *P. buruca*. The commissure of *P. globiformis* Boettger var. *healeyi* Reed from Yunnan seems to pass through the lunule instead of to the left of it (Reed 1927, pl. 18, fig. 6*a*); this variety is, therefore, probably not very close to *P. buruca*. *P. mansuyi* Reed 1927 differs from *P. buruca* in having the crenulations on the ribs restricted to the part of the shell away from the umbo and also seems to have a symmetrical lunule.

P. quadrata Trechmann (1917) from the New Zealand Carnian is more quadrate and has more anterior umbones than *P. buruca*, and *Cardita singularis* Healey from the Burmese Rhaetian is much more quadrate, more elongate, and probably much narrower.

P. buruca occurs in the Fogi Beds of west Buru, the *Nucula* Marl of Misol, and possibly in the Upper Triassic of Armenia and the Norian of Naiband, Persia.

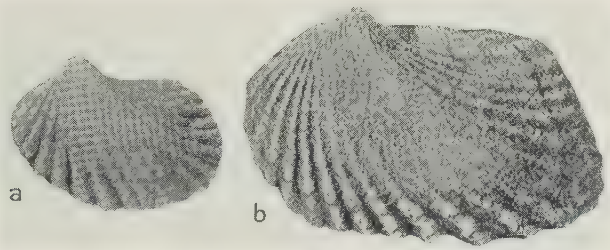
Palaeocardita trapezoidalis trapezoidalis (Krumbeck)

Text-fig. 10*a*

Cardita trapezoidalis Krumbeck 1913, p. 147, pl. 4, figs. 15*a*, *b*, *c*.
Cardita trapezoidalis Krumbeck nov. var. Jaworski 1915, p. 117, pl. 45, fig. 5.
?Cardita (*Palaeocardita?*) cf. *trapezoidalis* Krumbeck. Reed 1927, p. 224 .

Material. LL149*b*, a single left valve (text-fig. 10*a*). *Modiolus* Beds, Sumra Formation. L52742, Lees coll., Elphinstone Inlet, Oman, and LL369*b* from *Modiolus* Beds are *P. trapezoidalis* subsp. indet.

Morphology. Umbones slightly opisthogyrous. Outline trapezoidal, expanding posteriorly. Escutcheon slightly concave, meeting the commissural plane at right angles, invisible in lateral view; lunule deeply sunken. Primary crenulate radiating ribs, nine on siphonal area, ten on flank, separated by furrows each bearing, on the siphonal area and the posterior flank, a fine secondary rib. Lunule and escutcheon probably ornamented by fine radiating ribs.



TEXT-FIG. 10*a*. *Palaeocardita trapezoidalis trapezoidalis* (Krumbeck), left valve, LL149*b*, ×4, *Modiolus* Beds. 10*b*, *Palaeocardita trapezoidalis leesi*, subsp. nov., holotype, left valve, L52744, ×4. Elphinstone Inlet, Oman.

P. trapezoidalis trapezoidalis is recorded from the Fogi Beds of west Buru, the *Nucula* Marl and *Athyris* Limestone of Misol, and, possibly, the Upper Triassic of Yunnan.

Palaeocardita trapezoidalis leesi subsp. nov.

Text-fig. 10*b*

Cardita cf. *singularis* Healey. Lees 1928, p. 637 (not *Cardita singularis* Healey 1908).

Material. L52744 (text-fig. 10*b*), two well exposed left valves and a number of badly exposed valves. Lees coll., Elphinstone Beds, Elphinstone Inlet.

Comparison. Similar to *P. trapezoidalis trapezoidalis* except in the following features:

(*a*) More elongate. Dimensions (respectively L52744*a* and *b*): length, 13 mm., 10 mm.; height, 8 mm., 8 mm.; width 1·4 mm. (one valve).

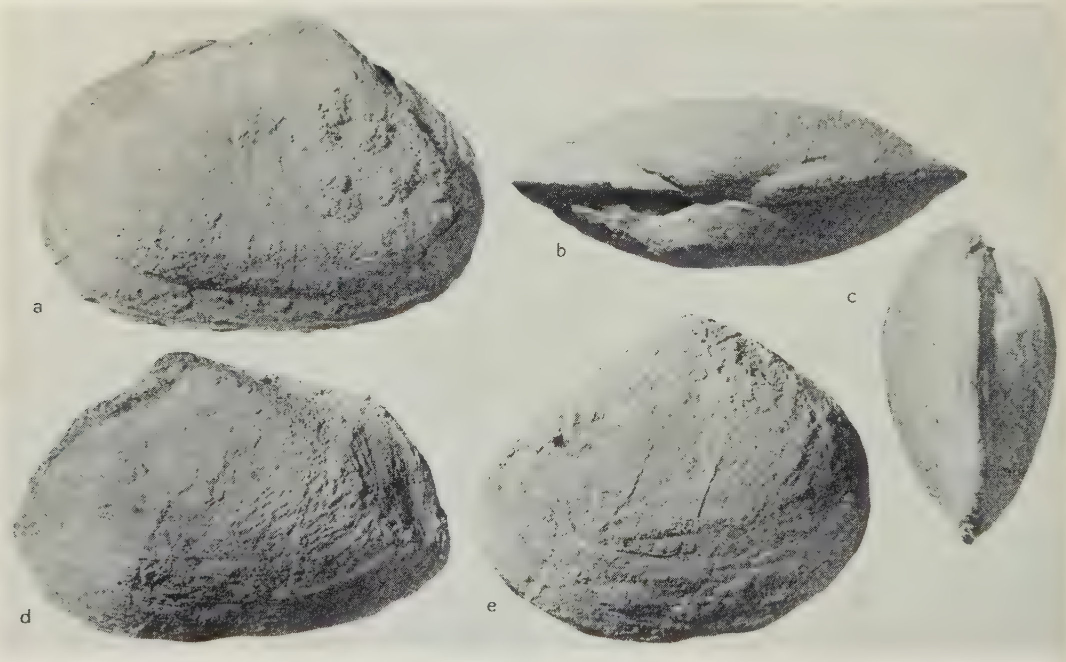
(*b*) Escutcheon less steeply inclined to commissural plane and hence clearly visible in lateral view.

(*c*) Less convex.

(*d*) With fewer ribs on the siphonal area (7 instead of 9) and more on the flank (13–15 instead of 10). There are six radial ribs on the escutcheon.

Remarks. Krumbeck seems to have made a mistake in describing the umbones of *P. trapezoidalis* as prosogyrous (1913, p. 147). They are clearly opisthogyrous in Jaworski's figure of the species (1915, pl. 45, fig. 56), Reed describes them as *retrorse* (1927, p. 224), and Krumbeck's anterior and posterior views (1913, pl. 4, figs. 5*b* and *c*) give the impression of opisthogyrous umbones. Lees compared his material with *Cardita singularis* Healey: in the opinion of the authors it agrees better with *P. trapezoidalis* since the umbones are opisthogyrous and the shape is trapezoidal with the greatest depth near the posterior end.

A series of good specimens of *P. trapezoidalis* from Oman would probably show that the subspecies *leesi* grades into the typical form: numerous bad specimens from Wadi Milaha and the Elphinstone Inlet cannot be placed in one or the other. It is just possible that the lower convexity and laterally visible escutcheon of *leesi* are really due to crushing though the specimens seem to be true shells rather than casts and do not seem distorted.



TEXT-FIG. 11. *Anodontophora griesbachi* Bittner, ×2, *Modiolus* Beds. *a–c*, LL476, × 2. *a*, Right valve; *b*, dorsal view; *c*, anterior view. *d*, Left valve of carinate variety, LL475, ×2. *e*, Right valve of tall variety, LL473, ×2.

Family ANTHRACOSIIDAE Amalitzky

Genus ANODONTOPHORA Cossman 1897

Anodontophora griesbachi Bittner

Text-figs. 3F, 11*a–e*

Anodontophora Griesbachi Bittner 1899, p. 60, pl. 8, figs. 14–16; Diener 1908*a*, p. 130, pl. 23, fig. 9; Krumbeck 1913, p. 55, pl. 3, figs. 21–23; Jaworski 1915, p. 109, figs. 22–24; Patte 1926, p. 163, pl. 10, fig. 36.

Anodontophora (*Anoplophora*) cf. *Griesbachi* Bittner. Mansuy 1908, p. 70, pl. 18, figs. 22, 23.

Material. LL463–LL484 (LL473, text-fig. 11*e*; LL475, text-fig. 11*d*; LL476, text-figs. 11*a–c*). All from Sumra Formation (mainly *Modiolus* Beds).

Morphology. Shell variable in outline, sometimes slightly carinate. Umbones slightly anterior and slightly prosogyrous, projecting above hinge-line and rather angular in lateral view. Hinge edentulous, with a weak cardinal plate in both valves. Strong ligament-nymphs present.

Comparison. Species of *Anodontophora* are variable and thus difficult to separate. *A. griesbachi*, for instance, varies in shape from almost trigonal to oblong (Krumbeck 1913, p. 56). The normal form also lacks a keel and has a convex posterior margin yet some Oman specimens are slightly carinate with almost straight backward-sloping posterior margin. *A. griesbachi* is like *A. fassaensis* (Wissmann) except that the latter has opisthogyrous instead of prosogyrous umbones (Bender, 1921, p. 55).

Distribution. A. griesbachi is known from the Fogi Beds of west Buru, the *Athyris* Limestone and *Nucula* Marl of the Misol Archipelago, from the *Tropites* Beds (= *Proclydonautilus griesbachi* Beds and *Halorites* Beds), the *Spiriferina griesbachi* Beds and *Sagenites* Beds of Painkhanda, and in the *Monotis* Beds and possibly the *Juvavites* Beds, and Quartzite Series of Spiti. It is also known from the Triassic of Tonkin. It may possibly occur in Europe as well since Bender (1921) stated that similar forms to *A. fassaensis* reached the Rhaetian in the Alps.

Anodontophora cf. *lettica* (Quenstedt)

Text-figs. 12*a–c*

Material. LL121, LL122 (text-figs. 12*a–c*). *Modiolus* Beds, Sumra Formation.

Umbones prosogyrous; no lunule, no escutcheon. No ornament except for variable concentric growth-lines. Apart from being thicker and having a straighter ventral margin this form resembles *Anodontophora lettica* from the Lettenkohle.

Family MEGALODONTIDAE Zittel

Genus MEGALODON Sowerby 1827

Megalodon ?hungaricum Kutassy

Plate 2, figs. 13, 17

COMPARE

Megalodos hungaricus Kutassy 1933, p. 17, pl. 2, figs. 4*a–c*; Terranini 1958, p. 164, pl. 6, fig. 11.

Material. LL427*b* (pl. 2, figs. 13, 17). Sumra Formation (exact horizon not known).

Morphology. Shell inequivalve with right valve two-thirds thickness of left. Umbones involute, prosogyrous. Left umbo more involute and prominent than right umbo. Lunule small, elongate, excavated. Siphonal area large, elongate, perpendicular to commissural plane and hence invisible in lateral view, about twice as wide on left valve as on right, separated from flanks in each valve by a very strong sharp keel; a very weak radial groove just anterior to keel in each valve. Ligament opisthodetic, supported by nymphs lodged in elongate ligament area about one-quarter the length of siphonal area. Escutcheon absent. Ornament of weak concentric growth-lines.

Remarks. M. hungaricum Kutassy was based on two internal casts, whereas the Oman specimen has the shell still preserved. This difference in preservation, together with the fact that the hinge is unknown, prevents a definite identification. Ascertainable features, however, agree very well. These include the strongly inequivalve nature, the very sharply defined siphonal area, and the absence of an escutcheon. The groove corresponding to the posterior adductor ridge in the left valve of the casts figured by Kutassy is probably represented in the Oman specimen by the shallow groove just in front of the siphonal area.

M. complanatum Gümbel, *M. laczkoi* Hoernes, and *M. boeckhi* Hoernes are less inequivalve than *M. hungaricum* and have the siphonal area less well defined. *M. cassianum* is less inequivalve. *M. ladakhense* Bittner is very similar to *M. hungaricum* but much less inequivalve.

M. hungaricum is recorded from the Norian Hauptdolomit of Hungary, and from the Norian of Songavazzo in Lombardy.

?Megalodon rostratiforme Krumbeck

Plate 2, fig. 22

?Megalodon rostratiforme Krumbeck 1913, p. 64, pl. 4, figs. 17*a–c*, 18–21, 22*a*, *b*.

Material. LL428, slab with numerous internal casts. LL429, slab with small weathered single valves (Pl. 2, fig. 22). Both from *Modiolus* Beds, Sumra Formation.

Morphology. Umbones prosogyrous. A rather strong keel, convex dorsally, runs from umbo to postero-ventral angle. Another rather strong keel from umbo to postero-dorsal angle defines the elongate narrow excavated escutcheon. A rather weak keel running forward from the umbo defines a deep lunule. Posterior muscle scar shows on some internal casts as a slightly raised rounded tetragonal area near the posterior end of the siphonal area.

Remarks. The Oman specimens agree almost exactly with those figured by Krumbeck and some of them show clearly the alate siphonal area that Krumbeck emphasized. The species varies greatly in height/length ratio but, like Krumbeck, we can see no reason to subdivide it on this basis. An extensive discussion of the affinities of this species is given by Krumbeck. *M. misolense* (Wanner and Knipscheer 1951, p. 59, pl. 5, figs. 6–9) is small like the present species but has only a weak siphonal keel and has the right valve somewhat more convex than the left.

The type of *?Megalodon rostratiforme* is from the Fogi Beds of west Buru.

Family PLEUROMYIDAE Zittel

Genus PLEUROMYA Agassiz 1842

Pleuromya himaica Diener

Plate 2, fig. 25

Pleuromya himaica Diener 1908*a*, p. 132, pl. 23, fig. 15.

Material. LL454–LL462: LL454–8, LL462 (Pl. 2, fig. 25) well preserved; LL459–61 ill preserved. All from *Modiolus* Beds, Sumra Formation.

Description. Umbones slightly prosogyrous. Dorsal part of posterior margin with fairly strong gape. Anterior gape possibly absent, at most only slight. Outline and height/length ratio very variable. Usually with a weak keel running vertically downwards from umbo and with slight sulcus behind the keel. Lunule cordate, defined by a sharp line on surface of shell. Escutcheon elongate, defined by a weak keel running backwards from umbo. Hinge margin (as deduced from internal cast) strongly thickened just before and behind the umbo of both valves. Just before and beneath the umbo is a flat triangular extension of the margin of the right valve. This overlaps a weaker extension of the margin of the left valve just beneath and behind the umbo. The posterior thickenings of the hinge margins of both valves probably correspond to ligament-nymphs.

DIMENSIONS (in mm.)

	Length	*Height*	*Thickness*
LL455 . . .	38	27	17
LL456 . . .	28	22	14
LL457 . . .	28	19	15
LL458 . . .	33	20	14

Remarks. The hinge of the Oman specimens, in so far as it can be studied, agrees best with *Pleuromya* as Douvillé (1907) described it. It might possibly indicate *Panopea* but we have found no sign of the enlarged, arched, left ligament nymph of that genus, which, moreover, usually has a much bigger posterior gape than the Oman specimens.

P. himaica Diener was founded on a single specimen and no others have since been described. Consequently nothing is known of the range of variation in this species. However, it was probably as variable as other species of *Pleuromya*. For this reason we identify the Oman specimens with it though none exactly agrees in shape with the type specimen. This also has a weak keel running almost vertically down from the umbo followed by a weak sinus, a feature which also occurs in many of the Oman specimens. A similar keel and sinus occur in the German Muschelkalk species *P. musculoides* (Schlotheim) figured by Bender (1921, p. 79, pl. 2, figs. 1–5, pl. 2, fig. 1). This species resembles *P. himaica* in shape and the two may perhaps be identical. This cannot be decided, however, without examining good material of both.

There are four published figures of the New Zealand Ladinian species *P. mariana* (Wilckens). Three of these figures (Marwick 1953, pl. 6, fig. 5; Wilckens 1927, pl. 8, figs. 12*a*, *b*, as *Pleuromya? sp.*) show the same specimen, which is like *P. himaica* and might at first be thought identical. The fourth published figure (Wilckens, 1927, pl. 8, fig. 6, as *Nucula mariana*) has, however, a much sharper umbo than *P. himaica*. The two species are therefore not the same though it is possible their ranges of variation overlap considerably.

P. suevica Rolle (1857, pl. 1, figs. 2–3), with which Diener compared the present species, is variable in shape but has more prominent, less anterior umbones than *P. himaica*. The same is true of the umbones of *P.* cf. *suevica* (Goetel 1917, pl. 9, fig. 8). *P. sulcatissima* Krumbeck (1913, p. 71, pl. 5, figs. 11*a*, *b*) may be related to *P. himaica* but has a much sharper vertical sulcus.

P. himaica occurs in the *Monotis* Beds of Spiti.

Family CARDIIDAE Fleming

Genus PROTOCARDIA Beyrich 1842

Protocardia rhaetica (Merian)

Plate 2, figs. 12, 16, 21

Cardium rhaeticum Merian *in* Escher v. d. Linth 1853, p. 19, pl. 4, figs. 40, 41.
Protocardia aff. *contusa* Healey. Krumbeck 1913, p. 67, pl. 4, figs. 24–28; ?Douglas 1929, p. 628. Not *Protocardia contusa* Healey 1908.
Protocardia proteus Krumbeck 1913, p. 69, pl. 5, figs. 2–10; ?Douglas 1929, p. 628.
Protocardia rhaetica (Merian). Jaworski 1915, p. 122, pl. 94, figs. 15, 16.
For other references to this species see Diener (1923, p. 224) and Kutassy (1931, p. 412).

Material. LL430 (Pl. 2, figs. 12, 16, 21), LL431–3. All internal casts from *Modiolus* Beds, Sumra Formation. L52748, Lees coll. (slab of limestone with several ill preserved specimens). Elphinstone Inlet, Oman.

Morphology. Umbones mesogyrous, prominent, touching. Shell sometimes slightly crenulate. Siphonal area with about thirteen fine radial ribs. Adductor scars sub-equal, limited towards umbo by fairly strong myophorial buttresses. Dorsal margin of posterior scar arcuate; dorsal margin of anterior scar bifid.

Comparison. We agree with Jaworski (1915, p. 123) who could see no essential difference between *P. proteus* Krumbeck 1913 and *P. rhaetica* (Merian). Both are highly variable in outline and in the prominence and position of the umbo and both have in common the absence or extreme weakness of the keel. *P. proteus* was said (Krumbeck 1913, p. 71) to have taller, more anterior, and more prosogyral umbones than the type specimens of *P. rhaetica* figured by Merian. This is true, but so have many English examples of *P. rhaetica*. The prominence of the umbones in *P. proteus* is probably partly due to the fact that the species was based on internal casts, most of them large. The smaller complete shells which Krumbeck (1913, p. 67) called *P.* aff. *contusa* Healey are probably well preserved juveniles of the *P. proteus* population. *P. contusa* Healey 1908 is more quadrate than most English *P. rhaetica*, though some of the latter are identical in form with *P. contusa* (Healey 1908); this, however, does not prove, as Healey asserts, that *P. contusa* occurs in England.

According to Krumbeck (1923, p. 216) *P. subrhaetica* is likewise more uniform in outline than *P. rhaetica*. Though close, the two species are not identical.

P. rhaetica is a widespread species in the Rhaetic of Europe. In Asia it is known from the *Nucula* Marl of Misol, the Fogi Beds of west Buru (as *P.* aff. *contusa* and *P. proteus*), and from the Naiband Calciferous Sandstone of Persia (as *P.* aff. *contusa* and *P. proteus*).

Family PANOPAEIDAE Zittel

Genus HOMOMYA Agassiz 1842

?Homomya sublariana Krumbeck

Plate 2, figs. 10, 11, 14

?Homomya sp. ind. aff. *larianae* Stoppani. Diener 1908*a*, p. 99.
?Homomya sp. ind. Diener 1908*a*, p. 133.
Homomya sublariana Krumbeck 1913, p. 72, pl. 5, figs. 12–14; ?Douglas 1929, p. 637.

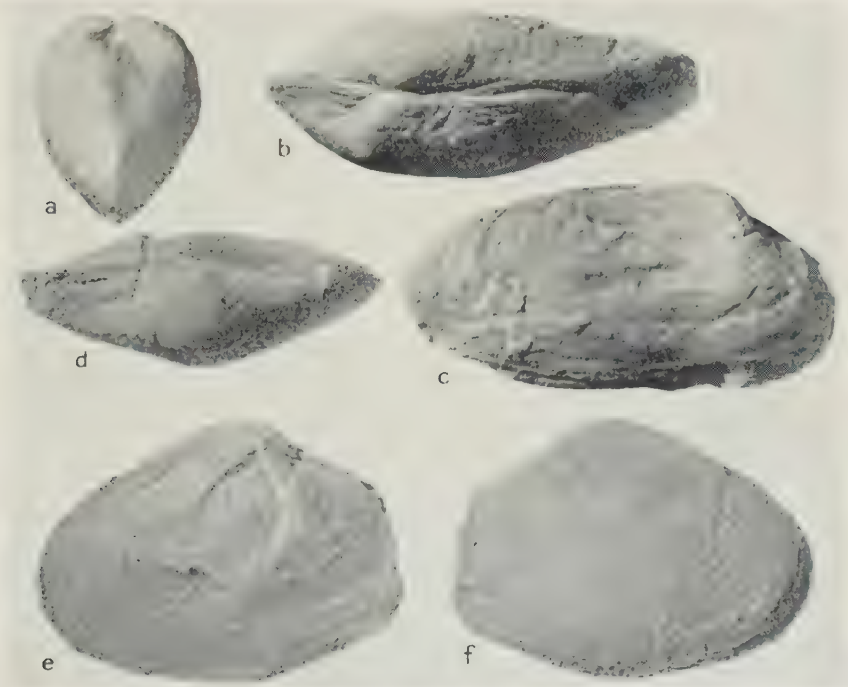
Material. LL452 (Pl. 2, figs. 10, 11, 14), LL453. *Lopha* Beds, Sumra Formation.

Morphology. Shell equivalve, gaping posteriorly. Umbones rather prominent, prosogyrous. Weak keels run from the umbo to the postero- and antero-ventral angles. Ornament of coarse, rounded, concentric folds which increase in amplitude ventrally. Near the umbo the primary folds are accompanied by secondary concentric folds.

Krumbeck (1913) describes radial rows of granules near the umbo but these are not visible in the Oman specimens.

Remarks. The generic allocation of this species is uncertain since nothing is known of its hinge. The best preserved of the above specimens does not seem to gape anteriorly which, if original, would not only exclude it from *H. sublariana* which is definitely stated by Krumbeck to gape anteriorly but also from *Homomya*. The apparent absence of an anterior gape, however, may be due to crushing. It is noteworthy that some of the forms recorded from the German Muschelkalk as *H. alberti* Voltz also have no obvious anterior gape (Bender 1921, pl. 1, fig. 1*b*). *H. lariana* (Stoppani) differs from *H. sublariana* in not having anterior and posterior keels: it therefore does not have the characteristic cylindrical flank of *H. sublariana*.

H. sublariana is recorded from the Fogi Beds of west Buru, the Calciferous Sandstone of Naiband, and, probably, from the *Juvavites* and *Monotis* Beds of Spiti.



TEXT-FIGS. 12*a–c*. *Anodontophora* cf. *lettica* (Quenstedt), LL122, 2·5, *Modiolus* Beds. *a*, Anterior view; *b*, dorsal view; *c*, right valve. 12*d–f*. *Thracia proavita* sp. nov., holotype, LL123, 2·5, *Modiolus* Beds. *d*, Dorsal view; *e*, left view; *f*, right valve.

Family THRACIIDAE Dall

Genus THRACIA Leach 1824

Thracia proavita sp. nov.

Text-figs. 12*d–f*

Material. LL123 (text-figs. 12*d–f*), LL124-5. From the *Modiolus* Beds, Sumra Formation.

Description. Shell thin-shelled, rather strongly inequivalve, right valve being more convex than left. Probably closed. Ornament of weak growth-lines. Umbones slightly posterior (beak distance = six-tenths), slightly opisthogyrous. Escutcheon clearly defined and siphonal area delimited by weak carina. Posterior part of shell somewhat rostrate, posterior margin straight and vertical. Ventral margin divided into two almost straight portions by obtuse angle directly beneath umbo. Length (LL123) *c.* 22 mm., height 14 mm., thickness *c.* 10 mm.

Comparison. Few *Thracia* are known from the Trias. *T. applanata* Krumbeck (1913, p. 74) is much larger and more elongate than *T. proavita*, and *T. prisca* Healey (1908, p. 61), from the Napeng Beds of Burma, has rather coarse concentric ribs.

T. proavita is similar in outline to the form described by Philippi (1898, p. 177, pl. 7, fig. 9) as *T. mactroides* (Schlotheim) from the Trigonodusdolomit. This German form, however, has the left valve more convex than the right. There is, incidentally, little resemblance between *T. proavita* and *Myacites mactroides* Schlotheim, which Bender (1921, p. 95) placed in *Pleuromya*, or *T. mactroides* (Schlotheim) as figured by von Seebach (1861, p. 636, pl. 15, figs. 5*a*, *b*, *c*).

Among Jurassic species of *Thracia* perhaps that most like *T. proavita* is *T. lens* (Agassiz 1845, p. 267, pl. 36, figs. 1–15, as *Corimya*) from the *oolite inferieur* of Switzerland. This species, however, lacks the blunt angle dividing the ventral margin of *T. proavita*, and is also less inequivalve.

REFERENCES

AGASSIZ, C. 1840–5. *Études critiques sur les mollusques.* 287 pp., 39 pls. Neuchâtel.

AGER, D. V. 1956. A Monograph of the British Liassic Rhynchonellidae, pt. 1, *Mon. Pal. Soc.* 1–50, pl. 1–4.

—— 1958. Ibid. pt. 2, 51–84, pl. 5–7.

ARKELL, W. J. 1932. *In* Arkell 1929–37, A Monograph of British Corallian Lamellibranchia. *Mon. Pal. Soc.* 1–392, pl. 1–56.

—— 1956. *Jurassic Geology of the World.* xv+806 pp. London.

BENDER, G. 1921. Die Homomyen und Pleuromyen des Muschelkalkes der Heidelberger Gegend. *Z. Deutsch. Geol. Ges.* **73** (1, 2), 24–112, pl. 1–4, tab. 1.

BERNARD, F. 1896. Sur le developpement et la morphologie de la coquille chez les lamellibranches. Deuxième note. Taxodontes. *Bull. Soc. géol. France*, (3) **24**, 54–82.

BITTNER, A. 1890. Brachiopoden der Alpinen Trias. *Abh. K.K. geol. Reichsanst.* **14**, 1–325, pl. 1–41.

—— 1891. Triaspetrefakten von Balia in Kleinasien. *Jahrb. K.K. geol. Reichsanst.* **41** (1), 13–116, pl. 1–3.

—— 1892. Neue Arten aus der Trias von Balia in Kleinasien. Ibid. **42** (1), 78–89, pl. 4–5.

—— 1895. Lamellibranchiaten der Alpinen Trias. I, Revision der Lamellibranchiaten von Sct. Cassian. *Abh. K.K. geol. Reichsanst.* **18** (1), 1–235, pl. 1–24.

—— 1899. Trias Brachiopoda and Lamellibranchiata. *Pal. Indica*, (15) **3** (2), 1–76, pl. 1–12.

—— 1912. Lamellibranchiaten aus der Trias des Bakonyer Waldes. *Res. Wiss. Erf. Balatonsees*, **1** (2), 1–106, pl. 1–9.

BLANFORD, W. J. 1872. Note on Maskat and Massandim on the East Coast of Arabia. *Rec. Geol. Surv. India*, **5** (3), 75–77.

BOEHM, G. 1906. Geologische Mittheilungen aus dem Indo-Australischen Archipel. I. Neues aus dem Indo-Australischen Archipel. *N. Jahrb. Min.* **20**, 385–412, pl. 15.

BOETTGER, O. 1880. Die Tertiärformation von Sumatra und ihre Tierreste. 3. Die Conchylien der unteren Tertiärschichten. *Palaeontograph.* Suppl. 3, **8a**, 1–120, pl. 1–12.

BUCKMAN, S. S. 1918. The Brachiopoda of the Namyau Beds, Northern Shan States, Burma. *Pal. Indica*, N.S., 3 (2), 1–254, pl. 1–21.

COX, L. R. 1935. The Triassic, Jurassic and Cretaceous Gastropoda and Lamellibranchia of the Attock District. Ibid. N.S., **20** (5), 1–27, pl. 1, 2.

—— 1944. On *Pseudolimea* Arkell. *Proc. Mal. Soc. London*, **26**, 74–88, pl. 2, 3.

—— 1952. Notes on the Trigoniidae, with outlines of a classification of the family. Ibid. **29**, 45–70, pl. 3, 4.

DAVIDSON, T. 1866. Notes on the Carboniferous Brachiopoda collected by Cpt. Godwin-Austen in the valley of Kashmere. *Quart. J. Geol. Soc. London*, **22**, 39–45, pl. 2.

DAVIES, A. M. 1935. *Tertiary Faunas*. **1**, 1–406, London.

DIENER, C. 1908*a*. Ladinic, Carnic and Noric Faunae of Spiti. *Pal. Indica*, (15) **5** (3), 1–157, pl. 1–24.

—— 1908*b*. Notes on some fossils from the sedimentary rocks of Oman. *Rec. Geol. Surv. India*, **36** (3), 156–63, pl. 24.

—— 1912. The Trias of the Himalayas. *Mem. Geol. Surv. India*, **36** (3), 1–176.

—— 1913. Triassic faunae of Kashmir. *Pal. Indica*, N.S., **5** (1), 1–133, pl. 1–13.

—— 1923. Lamellibranchiata triadica. *Foss. Cat. Animalia*, **19**, 1–257.

DOUGLAS, J. A. 1929. A marine Triassic fauna from Eastern Persia. *Quart. J. Geol. Soc. London*, **85**, 624–50, pl. 43–46.

—— and ARKELL, W. J. 1932. The stratigraphical distribution of the Cornbrash. 2. The North-Eastern Area. Ibid. **88**, 112–70, pl. 10–12.

DOUVILLÉ, H. 1907. Les Lamellibranches cavicoles ou Désmodontes. *Bull. Soc. géol. France*, (4) **7**, 96–114.

ESCHER v. d. LINTH, A. 1853. Geologische Bemerkungen über das nördliche Vorarlberg und einige angrenzenden Gegenden. *Nouv. Mem. Soc. Helvet. Sci. Nat.* **13**, 1–135, pl. 1–10.

FISCHER, P. H. 1925. La persistance des couleurs parmi les fossiles du trias moyen. *J. Conchyliologie*, **69** (1), 5–12, pl. 1–6.

FLEMING, C. A. 1953. A Triassic Oyster from New Zealand. *N. Zealand J. Sci. Tech.* **35**, 276–8.

GOETEL, W. 1917. Pietro retyckie i najdolniejszy lias seryi relowej w. Tatrach. Die rhätische Stufe und der unterste Lias der subtatrischen Zone in der Tatra. *Bull. international Acad. Sci. Cracovie*, 1–231, pl. 7–12.

HAUER, F. U. 1857. Ein Beiträg zur Kenntnis der Fauna der Raibler-Schichten. *Sitzb. Ak. Wiss. Wien*, **24**, 537–66.

HEALEY, M. 1908. Fauna of the Napeng Beds or Rhaetic Beds of Upper Burma. *Pal. Indica*, N.S., **2** (4), 1–88, pl. 1–10.

HOHENSTEIN, V. 1913. Beiträge zur Kenntnis des mittleren Muschelkalkes und des unteren Trochitenkalkes am östlichen Schwarzwaldrand. *Geol. Pal. Abh.* N.F., **12** (2), 173–272, pl. 12–19.

HUDSON, R. G. S. 1960. The Permian and Trias of the Oman Peninsula. *Geol. Mag.* **97** (4), 299–308.

——, MCGUGAN, A., and MORTON, D. 1954. The structure of the Jebel Hagab area, Trucial Oman. *Quart. J. Geol. Soc. London*, **110**, 121–52, pl. 5–8.

—— and CHATTON, M. 1959. The Musandam Limestone (Jurassic to Lower Cretaceous) of Oman, Arabia. *Notes Mém. Moyen-Orient*, **7**, 69–93. Mus. nat. d'Hist. nat., Paris.

JAWORSKI, E. 1915. Die Fauna der Obertriadischen Nuculamergel von Misol. *Pal. Timor*, **2** (5), 73–174, pl. 43–45.

KRAFFT, A. VON 1900. Stratigraphical notes on the Mesozoic Rocks of Spiti. *Gen. Rep. for 1899–1900, Geol. Surv. India*, 199–230.

KRUMBECK, L. 1913. Obere Trias von Buru und Misol. *Palaeontograph., Suppl. 4*, **2** (1), 1–161, pl. 1–11.

—— 1914. Obere Trias von Sumatra. Ibid. **2** (3), 197–266, pl. 15–17.

—— 1922. Stratigraphische Ergebnisse von Niedermayers Reise durch Persien. *Centralbl. Min.* 1922, 19–23.

—— 1923. Brachiopoden, Lamellibranchiaten und Gastropoden aus der oberen Trias der Insel Seran. *Palaeontograph.*, Suppl. 4, **3** (5), 186–245, pl. 12–15.

—— 1924. Die Brachiopoden, Lamellibranchiaten und Gastropoden der Trias von Timor. 2, Palaontologischer Teil. *Pal. Timor*, **4**, 143–417, pl. 179–98.

KUTASSY, A. 1931. Lamellibranchiata triadica, 2. *Foss. Cat. Animalia*, **51**, 260–477.

—— 1933. Beiträge zur Kenntnis der Fauna des Norischen Hauptdolomites in Ungarn. *Földt. Közlöny*, **63**, 12–19, pl. 1–2.

KUTASSY, A. 1934. Het Palaeozoikum en de Trias van Oost Celebes. *Verh. Geol.-Mijnb. Gen. Nederland en Kol., Geol. ser. d*, **10**, (3), 295–305, pl. 3, 4.

—— 1935. Két uj *Indopecten* faj az erdélyi triászból—Zwei neue *Indopecten*-Arten aus der Siebenbürgischen Trias. *Mat. u. Naturw. Anz.* (*Ung. Akad. Wiss.*), **53** (2), 498–507.

LEES, G. M. 1928. The geology and tectonics of Oman and of parts of South-Eastern Arabia. *Quart. J. Geol. Soc. London*, **84** (4), 585–670, pl. 41–51.

MANSUY, H. 1908. Contribution à la carte géol. Indochine. Paléontologie. *Service des Mines, Hanoi*, 1–73, pl. 1–18.

MARWICK, J. 1953. Divisions and faunas of the Hokonui System (Triassic & Jurassic). *Pal. Bull. New Zealand Geol. Surv.* **21**, 1–141, pl. 1–17.

MERLA, G. 1933. Fossili triasici della Depsang. *Spediz. Fillippi*, (2) **11**, 1–124, pl. 4–6.

MIDDLEMISS, C. S. 1909. Gondwanas and related marine sedimentary systems of Kashmir. *Rec. Geol. Surv. India*, **37**, 286–327, pl. 26–34.

MOISEEV, A. S. 1936. Les nouveaux genres des Rhynchonellidae du triasique et liasique. *Tr. Soc. Nat. Leningrade* (*Sec. Géol. Min.*), **65** (1), 39–50, pl. 1.

OPPEL, A. 1865. Ueber ostindische Fossilreste (Fortsetzung). *Pal. Mitt. Mus. K. Bayer Staates*, 289–302, pls.

PARONA, C. F. 1889. *Studio monografico della fauna raibliana di Lombardia.* 156 pp., 13 pls. Pavia.

PATTE, E. 1926. Études paléontologiques relatives à la géologie de l'est du Tonkin (Paléozoique et Trias). *Bull. Serv. géol. Indochine*, **15** (1), 1–199, pl. 1–12.

PHILIPPI, E. 1898. Die fauna des unteren Trigonodus-Dolomits. . . *Jahrb. Ver. Vat. Naturk. Württemberg.* **54**, 145–227, pl. 4–9.

QUENSTEDT, W. 1930. Die Anpassung an die grabende Lebensweise in der Solenomyiden und Nuculaceen. *Abh. Geol. Palaeont.*, N.S., **18**, 1–119, pl. 1–3.

REED, F. R. C. 1927. Palaeozoic and Mesozoic fossils from Yun-nan. *Pal. Indica*, N.S., **10** (1), 1–291, pl. 1–20.

ROBINSON, V. N. 1937. The Stratigraphy of the Upper Trias of the North Caucasus and Transcaucasia. *Nat. Centr. Geol. Prospecting Inst.* **3**, 37–40.

ROLLE, F. 1857. Ueber einige an der Grenze von Keuper und Lias in Schwaben auftretende Versteinerungen. *Sitzb. Ak. Wiss. Wien*, **26**, 13–32, pl. 1.

SAURIN, E. 1941. Lamellibranches du Trias supérieur de Hoa-Huynh (Sud-Annam). *Bull. Serv. géol. Indochine*, **26** (3), 1–16, pl. 1–2.

SCHENCK, H. G. 1934. Classification of Nuculid Pelecypods. *Bull. Mus. Roy. Hist. Nat. Belg.* **10** (20), 1–78, pl. 3–5.

SCHLOTHEIM, E. F. 1820–3. *Die Petrefactenkunde, etc.* 437 pp., 18 pl. App. I, 100 pp., 21 pl. App. II, 114 pp., 16 pl. Gotha.

SEEBACH, K. VON 1861. Die Conchylien-Fauna der Weimarischen Trias. *Z. Deutsch. Geol. Ges.* **16**, 551–666, pl. 14–15.

SEIDLITZ, W. VON 1913. *Misolia*, eine neue Brachiopoden-Gattung aus den Athyridenkalk von Buru und Misol. *Palaeontograph.*, Suppl. 4, **2** (2), 163–93, pl. 12–14.

STOLICZKA, F. 1866. Geological Sections across the Himalayan Mountains, from Wang-tu Bridge on the River Sutlej to Sunddo on the Indus: with an account of the formation in Spiti; accompanied by a revision of all known fossils from that district. *Mem. Geol. Surv. India*, **5**, 140–54, pl. 1–10.

STOPPANI, A. 1861. Géologie et paléontologie des couches à *Avicula contorta* en Lombardie. *Pal. Lombarde*, **3**, 1–267, pl. 1–60.

TERRANINI, D. 1958. Studio paleontologico sul Norico di Songazzo (Bergamo), I. *Riv. Ital. Pal. Strat.* **64** (2), 143–82, pl. 6, 7.

TRECHMANN, C. T. 1917. The Trias of New Zealand. *Quart. J. Geol. Soc. London*, **73**, 165–245, pl. 17–25.

VAUGHAN, A. and REYNOLDS, S. H. 1904. The Rhaetic beds of the S. Wales Direct Line. *Quart. J. Geol. Soc. London*, **60**, 194–214, pl. 18.

WAAGEN, L. 1907. Die Lamellibranchiaten der Pachycardienstuffe der Seiser Alm. *Abh. K.K. geol. Reichsanst.* **18** (2), 1–180, pl. 25–34.

WANNER, J. 1907. Trias-Petrefakten der Molukken und Timorarchipels *in* G. Boehm: Geologische Mittheilungen aus dem Indo-Australischen Archipel. 4. *N. Jahrb. Min.* **24**, 161–220, pl. 7–12.

WANNER, J. and KNIPSCHEER, H. C. G. 1951. Beiträge zur Paläontologie des Ostindischen Archipels; 20, Neue Versteinerungen aus den norischen *Nucula*-Mergeln von Misol. *N. Jahrb. Geol. Pal.* **94** (1), 49–66, pl. 5.

——, KNIPSCHEER, H. C. G., and SCHENK, E. 1952. Zur Kenntnis der Trias der Insel Seran (Indonesien). *Eclog. Geol. Helvet.* **45**, 53–87, pl. 3, 4.

WILCKENS, O. 1927. Contributions to the Paleontology of the New Zealand Trias. *Pal. Bull. New Zealand Geol. Surv.* **12**, 1–65, pl. 1–9.

WÖHRMANN, S. F. VON 1889. Die Fauna der sogenannten *Cardita*- und Raibler-Schichten in den Nordtiroler und Bayerischen Alpen. *Jahrb. K.K. geol. Reichsanst.* **39**, 181–258, pl. 5–10.

—— 1893. Die Raibler Schichten nebst kritischer Zusammenstellung ihrer Fauna. Ibid. **43**, 617–768, pl. 13.

ZUGMAYER, H. 1882. Untersuchungen über rhätische Brachiopoden. *Beitr. Paläont. Oesterr.-Ung.* **1**, 1–42, pl. 1–4.

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THE PERMIAN BRACHIOPOD GENUS *HORRIDONIA* CHAO

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ABSTRACT. *Horridonia* is redefined to include two variable species, *H. horrida* and *H. timanica*. The lectotype of the former is redescribed and figured. *H. timanica* is a Russian and Arctic species, *H. horrida* European. Both species occur in Greenland. The genera *Sowerbina* Fredericks emend. Dunbar and *Pleurohorridonia* Dunbar are considered synonymous with *Horridonia*.

IN the classification of the Productidae, the surface sculpture of the ventral valve has always played an important role (discussion in Chao 1927). However, Tschernyschew (1902) considered the form of both valves and the shell cavity, and Fredericks (1915) defined three groups on this basis which he called *Producti typici* α, *P. typici* β, and *P. proboscidei*. He criticized Thomas's (1914) classification and considered that the surface sculpture was an adaptive character, depending on the mode of life of the organism.

Chao (1927) recognized three principle factors: surface sculpture, the form of the valves and the shell cavity, and the internal characters. He defined *Horridonia* (p. 24) as: 'Characterised by strong median sinus and fold, slightly convex brachial valve and a few but very stout hollow spines. Type, *Productus horridus* Sowerby and *Productus timanicus* Stuckenberg.' The following year he expanded this slightly (Chao 1928, p. 62) as follows: 'Forms belonging to this sub-section, [*Horridonia*] . . . possess essentially the same characteristic outline of typical *Productus*, but are without either plicae or wrinkles. The median sinus and fold are rather pronounced and the surface is marked only by irregularly distributed, strong and erect spines. Some indefinite plicae are sometimes present, indicating occasional survival of the plica-making impulse.'

In 1928 Fredericks, presumably ignorant of Chao's work, produced a classification of the genus *Productus* based primarily on his three morphological groups and secondarily on the surface sculpture of the visceral part of the valves. He defined a genus *Sowerbina* in Russian (Fredericks 1928) with an English summary (p. 789) as follows: 'The shell is productiform and has a plain surface. Sometimes a thin granulation is observed on the surface of the valves. Sometimes are seen marks of a punctate structure. Type *Productus timanicus* Stuckenberg spec.'

Neither of these authors has given a satisfactory definition of a genus which includes *P. horridus* Sowerby and *P. timanicus* Stuckenberg. Chao's name, *Horridonia*, has priority. He designated two genosyntypes, *P. horridus* Sowerby and *P. timanicus* Stuckenberg, the first of which was selected as genolectotype by Schuchert and LeVene (1929). Later writers have enlarged the genus to include various forms having a smooth shell surface with scattered spines and often a ribbed trail. Branson (1948) lists thirteen species, some of which had been referred to *Avonia* by previous authors; some were put into new genera by Muir-Wood and Cooper (1960) and others are synonyms or inadequately described.

Palaeontology, Vol. 4, Part 1, 1961, pp. 42–53, pls. 3–5.]

Dunbar (1955) has recognized the genus *Sowerbina* Fredericks as distinct from *Horridonia* Chao. Dunbar's diagnosis of *Sowerbina* (p. 96) is as follows: 'Productids of moderate to strong curvature (not geniculate), having a narrow ventral sulcus between strong visceral humps; cardinal extremities extended into conspicuous auricles; surface non-costellate, ornamented by minute crinkly pustules; spines large, specialized, and localized as follows: the dorsal valve bears a single row of cardinal spines plus a pair (rarely more or less) of large spines on each auricle, ventral valve without cardinal or auricular spines but having 1 to 3 (rarely more) radial rows of spines on the visceral humps. Generotype: *Productus timanicus* Stuckenberg.'

Sowerbina as defined by Dunbar differs essentially from *Horridonia* Chao in the absence of cardinal and auricular spines on the ventral valve. Except in this character, the extent and size of the spines in *P. horridus* and *P. timanicus* are extremely variable. It seems best at present to refer both species to *Horridonia*.

Genus HORRIDONIA Chao

1927 *Horridonia* Chao, p. 25.
1928 *Sowerbina* Fredericks, p. 778.
1955 *Pleurohorridonia* Dunbar, p. 89.
1955 *Sowerbina* Fredericks, Dunbar, p. 95.

Generic description. Productids, trapezoidal in outline, with auricles moderately to strongly developed. Ventral valve moderately to strongly convex, not geniculate; median sulcus deep to very shallow, dividing more or less prominent visceral humps. Dorsal valve almost flat to markedly concave, with median fold. Surface of both valves smooth or with a very fine granular sculpture; visceral surface of ventral valve usually with erect spines; anterior part of this valve often with irregular costae. Long cardinal and auricular spines present on both valves or dorsal valve only. Interior of ventral valve with a prominent adductor muscle platform. Interior of dorsal valve with median septum between triangular adductor muscle impressions. Cardinal process trilobed, the central lobe bifid, posterior surface of lobes pectinated.

Type species by subsequent selection of Schuchert and LeVene (1929, p. 68): *Productus horridus* J. Sowerby 1823.

Horridonia horrida (J. Sowerby)

Plate 3, figs. 1–12; Plate 5, figs. 5, 7–8

1823 *Productus horridus* J. Sowerby, p. 17, pl. 319, fig. 1.
1829 *Producta calva* J. de C. Sowerby, p. 115, pl. 560, figs. 2–6.
1846 *Productus geinitzianus* de Koninck, p. 264, pl. 15, figs. 3 *a–d* (reprinted in de Koninck 1847, p. 156, pl. 15, figs. 3 *a–d*).
1848 *Productus latirostratus* Howse, p. 256.
1848 *Productus umbonillatus* King, p. 8.
1850 *Productus horridus* Sow.; King, p. 87, pl. 11, figs. 1–13.
1850 *Productus umbonillatus* King, p. 92, pl. 11, figs. 14–18.
1858 *Productus sulcatus* Sow, var. *borealis* Haughton, part, p. 242, pl. 7, figs. 1 and 7.
1861 *Productus horridus* Sow.; Geinitz, p. 103, pl. 19, figs. 11–17.
1861 *Productus latirostratus* Howse; Geinitz, p. 102, pl. 19, figs. 7–10.
1861 *Productus geinitzianus* de Koninck; Geinitz, p. 105, pl. 19, figs. 18–21.
? 1908 *Productus borealis* Whitfield, part, not Haughton, p. 55, pl. 2, fig. 11.

1909 *Productus horridus* Sow.; Eisel, p. 33, figs. 1–10.
1933 *Productus horridus* Sow.; Frebold, pp. 18, 20, 21, pl. 2, figs. 10–13, pl. 3, figs. 9*a–d*.
1937 *Productus horridus* Sow.; Malzahn, p. 8, pl. 1, figs. 1–23, pl. 2, figs. 1–20.
1955 *Pleurohorridonia scoresbyensis*, Dunbar, p. 90, pl. 11, figs. 1–10.
1959 *Horridonia horrida* (Sow.); Stepanov, p. 191, pl. 1, figs. 1–6.

Type specimen. The specimen figured by J. Sowerby (1823, pl. 319, fig. 1), British Museum No. B60972, has been generally accepted as the type, e.g. King 1850, p. 89, footnote. It is here formally designated the lectotype.

Type locality. The origin of the lectotype is obscure. Sowerby (1823, p. 17) records the locality as follows: 'Not very rare in Derbyshire, communicated by Mr. White Watson, from the seventh bed of his first Limestone, probably Magnesian, as it is above the coal series.' White Watson (1811, p. 5) describes the seventh bed of his first limestone, which forms the base of the Lower Magnesian Limestone, as follows: 'Shell-Limestone, of a more compact texture, of a bluish grey colour, containing petrified Bivalve Shells; this stone is in request for making Lime for Agriculture, and quarries of it are worked at Bolsover, Oxcroft, Barlborough, Palterton, and Houghton.' Gibson and Wedd (1913, p. 90) record disused quarries at Limekiln Field, north of Bolsover. This exposure is now much overgrown and on a recent visit no fossils were found. However, farther north at Aldfield, near Ripon, and at East Thickley in County Durham, *H. horrida* occurs in a hard, bluish limestone at about the same horizon as the limestone at Bolsover. The type locality of *H. horrida* may well be the disused quarry in Limekiln Field, Bolsover, Derbyshire (Grid. Ref. SK/474712). There is little doubt that the lectotype was collected from the Lower Magnesian Limestone.

Specific diagnosis. Horridonia with cardinal and auricular spines on both valves.

Description. The lectotype is figured on Plate 3, figs. 1*a–c*. It has a strongly convex auriculate ventral valve with a very broad sulcus and a double row of cardinal spines. On the anterior part of the ventral valve are irregular and rather coarse costae. The dorsal valve is moderately concave and has two rows of cardinal spines, the anterior row consisting of two or three spines only. The auricle is deflected to allow the passage of a large auricular spine. Sowerby's figure, although crude, is truer than King's (1850, pl. 11, fig. 2) which is an imagined restoration. In other specimens the sulcus may be narrower (Pl. 3, fig. 2*b*) or be almost absent (Pl. 3, fig. 7). The relative size of the auricles varies (Pl. 3, cf. figs. 4–6) and costae may be absent from the anterior part of the ventral valve. Only one row of cardinal spines may be present (Pl. 3, fig. 2*a*) and the auricular spine or spines are often small, though rarely absent. A variable number of visceral spines is present on the ventral valve (Pl. 3, cf. figs. 8–10), and occasionally on the dorsal valve (Pl. 3, fig. 12). In some specimens visceral spines are completely absent. The internal features are best studied on the internal moulds abundant in the Middle Magnesian Limestone at Humbledon Hill quarry, County Durham. Latex casts were made

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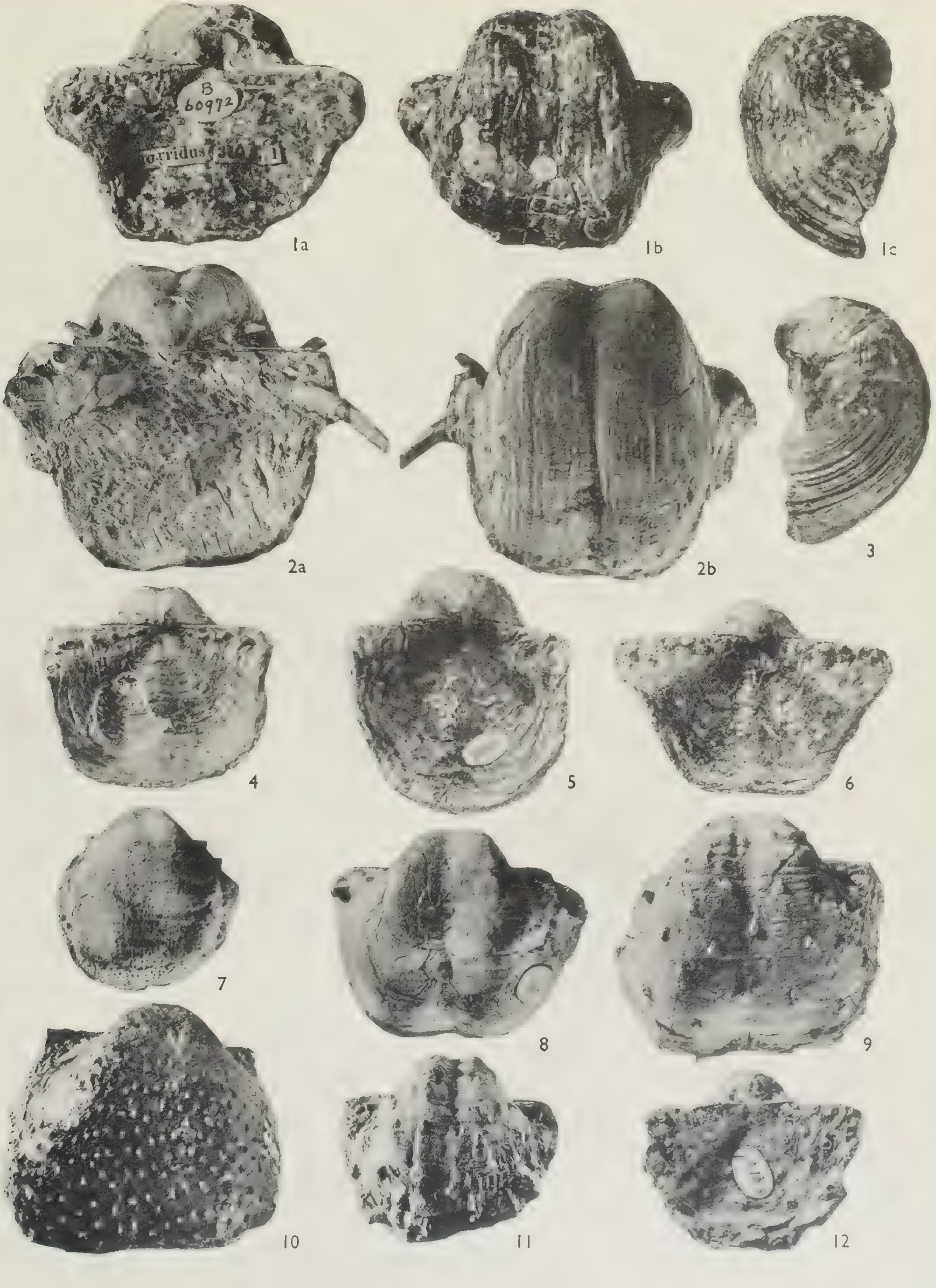
EXPLANATION OF PLATE 3

Figs. 1–12. *Horridonia horrida* (J. Sowerby). Natural size. 1*a–c*, Dorsal, antero-ventral and lateral views of the holotype, B.M. B60972, figured by Sowerby 1823, pl. 319, fig. 1. Lower Magnesian Limestone, ? Bolsover, Derbyshire. 2*a–b*, Dorsal and ventral views, S.M. G823, Lower Magnesian Limestone, Harworth Main Sinking, Doncaster, Yorkshire. 3, Lateral view, B.M. B39307, Lower Zechstein, Trebnitz, Gera. 4, Dorsal view, B.M. B8727, Lower Zechstein, Gera. 5, Dorsal view, B.M. 65631, Budenguen. 6, Dorsal view, B.M. B39300, Posneck, Thuringia. 7, Ventral view, S.M. G1074, Lower Magnesian Limestone, Scar Lime Kilns, Well, Ripon, Yorkshire, G.R. SE/267813. 8, Ventral view, B.M. B5817, Lower Magnesian Limestone, East Thickley, Durham. 9, Ventral view, B.M. B39302, Lower Zechstein, Trebnitz, Gera. 10, Ventral view, B.M. 73248, same locality as fig. 9, 11–12, Ventral and dorsal view of two specimens, B.M. 73163, same locality as fig. 9.



GOBBETT, *Horridonia horrida*, × 1

from these specimens (Pl. 5, figs. 5, 7–8). In the interior of the ventral valve, the umbone and hinge-line are quite smooth. The adductor muscle impressions lie on a raised platform which is parallel-sided, rounded anteriorly, and extends slightly anterior to the divaricator impressions. The latter are rounded-triangular in outline and are abruptly terminated anteriorly. The anterior and lateral parts of the valve are studded with small elongated pits. In the dorsal valve interior there is a smooth, flat area at the base of the cardinal process. The latter has three serrated lobes, the central one being bifid (Pl. 5, fig. 5). The adductor muscle impressions form a convoluted pattern and are triangular in outline. A median septum arises between these and runs anteriorly as far forward as the anterior border of the 'brachial impressions'. The latter are approximately oval with a raised rim. The posterior part of the valve is smooth or pitted. The anterior part has evenly spaced pustules, becoming larger and more densely spaced anteriorly.

Discussion. The representatives of this species show a great variation in external appearance. Forms from the English Zechstein were early recognized as distinct species, *Productus horridus* J. Sowerby, *P. calvus* J. de C. Sowerby, and *P. latirostratus* Howse = *P. umbonillatus* King. The last of these differs from other forms of *H. horrida* in its smaller size, low convexity of the ventral valve, and flattened umbo. It appears to be a stunted form, which perhaps lived in a less favourable environment. Eisel (1909) named and described six forms from the Zechstein of the Gera basin. He considered these to be varieties of *P. horridus*. The first of Eisel's varieties, var. *initialis*, was not found above bed 3, the 'Dachfloz' of the Gera Zechstein, but all the other varieties occurred together in bed 4, the 'Unterer Kompakter Zechstein'.

Malzahn (1937) gave a full discussion of *Productus horridus* and its varieties. He thought *P. timanicus* was a closely related ancestral species, connected with *P. horridus* by transitional forms. A specimen from central east Greenland described by Frebold (1933) as *P. horridus* Sow. var. *granulifera* Toula was cited as one of these transitional forms. Toula's variety is in fact *Horridonia timanica* (Stuck.). Frebold's specimen has cardinal spines on the ventral valve and belongs to *H. horrida*. Malzahn investigated the distribution of Eisel's varieties in new exposures of beds 3–5 in the Gera Zechstein. He confirmed that, although *initialis* was restricted to bed 3, any one of the other varieties was not restricted to any particular horizon within bed 4 and was thus of no stratigraphic use. In order to ascertain the relations between the varieties of *P. horridus* and *P. timanicus*, Malzahn selected three shell characters, the length of the hinge-line, the height of the ventral valve and the curvature of the ventral valve from umbo to anterior border. He subjected these to a statistical analysis and concluded that, with regard to these three characters, *P. timanicus* and four varieties of *P. horridus* form a genetically connected group. One variety, var. *hoppeianus*, does not fall into this group and on this statistical basis cannot be shown to be genetically related to it. However, if characters other than those selected for analysis are used, e.g. cardinal spines, *hoppeianus* would agree with the other varieties of *P. horridus* while *P. timanicus* would appear as the exception. A similar result would probably be obtained if internal characters were treated, e.g. the relative length of the septum in the dorsal valve.

Malzahn considered also the dependence of individual varieties on the type of sediment on which they lived. The shells in the Zechstein of Gera are commonly found with well preserved cardinal spines reaching a length of 10 cm., so that it may be assumed that they constitute a biocoenose. They are restricted to a limestone or marly facies and are not found in the basal Zechstein conglomerate nor in the upper beds, which approach an evaporite facies. He concluded that the $CaCO_3$ content of the sediment may be directly related to the size but not the form of the shells. However, populations do not seem to be centred round one particular variety and may include several varieties with transitional forms (Eisel 1909; Malzahn 1937).

The two syntypes of *P. sulcatus* var. *borealis* Haughton, which were kindly lent to me from the National Museum of Ireland, represent two species. The larger specimen belongs here. It is well preserved and agrees precisely with a specimen in the Sedgwick Museum, G 832 (Pl. 3, fig. 2*a–b*), from the Lower Magnesian Limestone of Yorkshire. The smaller specimen, described by Haughton as a juvenile specimen, is generically distinct from *Horridonia*.

Some specimens from central east Greenland were described by Dunbar (1955) as a new species, *Pleurohorridonia scoresbyensis*. The diagnostic characters of this species, i.e. the ribbed anterior part of the ventral valve, the auricular spines, and the concentric granular surface sculpture, are all present on *Horridonia horrida*. Dunbar's form is perhaps nearest to Eisel's var. *hoppeianus*.

The great variation of *H. horrida* is illustrated in Plate 3. Varietal names are not recognized by the International Commission on Zoological Nomenclature and, although it may be convenient to describe the forms of *H. horrida* as subspecies, I think this is unwise. The variable characters, external form and spinosity, may be phenotypic. Also, intermediate forms occur and the 'varieties' do not appear to be of stratigraphical use.

Distribution (text-fig. 1). *H. horrida* is found in the English Zechstein from the Marl Slate to the middle part of the Middle Magnesian Limestone (Reef B of Trechmann 1925), after which it was presumably exterminated by an inimical environment. In Germany it occurs in the Kupferschiefer and Zechsteinkalk of the Lower Zechstein. Again it seems that an inimical environment set in after these beds had been deposited. In central east Greenland this species appears common and widespread. Dunbar records it from the Schucherts Flod area in southern Scoresby Land, Clavering Ø, Nathorsts Fjord area, and at many other places. It is also found in blocks of Permian limestone in Triassic conglomerate of the Kap Stosch area. Haughton's specimen came from Hillock Point, Melville Island; Whitfield's was collected from Cape Sheridan, at 82° 27′ N. in Ellesmere Island. Recently Stepanov (1959) has described a Zechstein brachiopod fauna including *H. horrida* from two bore-holes in southern Lithuania. *H. horrida* is unknown in arctic Europe and Russia.

Horridonia timanica (Stuckenberg)

Plate 4, figs. 1–4; Plate 5, figs. 1–4, 6, 9–13

1875 *Productus timanicus* Stuckenberg, p. 86, pl. 1, figs. 1–7.
1875 *Productus horridus* Sow. var. *granuliferus* Toula, p. 232, pl. 6, figs. 3*a–c*.
1902 *Productus timanicus* Stuck., Tschernyschew, p. 638, pl. 30, fig. 5; pl. 57, figs. 1–6; text-figs. 78, 79.
?1908 *Productus borealis* Whitfield, part, not Haughton, p. 55, pl. 1, fig. 1.
1914 *Productus timanicus* Stuck.; Wiman, p. 75, pl. 17, figs. 19–21, pl. 18, figs. 1–6.
1914 *Productus inflatus* Wiman, part, not McChesney, pl. 14, fig. 1, pl. 15, figs. 3, 5.
1934 *Ruthenia granulifera* (Toula); Fredericks, p. 39, pl. 3, figs. 1–8, pl. 4, figs. 1–3.

1937 *Productus* (*Horridonia*) *borealis* Stepanov, not Haughton, p. 115, 175, pl. 4, figs. 1–3, pl. 5, figs. 1–4.
1937 *Productus* (*Horridonia*) *timanicus* Stuck.; Frebold, p. 21, pl. 4, fig. 4, pl. 7, figs. 2–3.
?1939 *Productus* (*Horridonia*) *borealis* Licharew and Einor, not Haughton, p. 55, 206, pl. 10, figs. 6–11, pl. 11, figs. 1–5.
1955 *Sowerbina maynci* Dunbar, p. 97, pl. 13, figs. 1–9.
1955 *Sowerbina rudis* Dunbar, p. 101, pl. 14, figs. 1–7, pl. 15, figs. 1–6.

Type specimen. Stuckenberg (1875) mentioned no holotype. I designate as lectotype the specimen figured by Stuckenberg (1875, pl. 1, figs. 3 *a–c*).

Type locality. The specimens described by Stuckenberg were collected from the River Indiga section of the Timan 'mountain limestone' (67° 30′ N. 49° E.).

Specific diagnosis. *Horridonia* with cardinal and auricular spines on the dorsal valve only.

Description. This is based mainly on eighty specimens from Spitsbergen, now in the Sedgwick Museum, Cambridge.

The shell is auriculate with a trapezoidal to pentagonal outline. It is generally larger than *H. horrida* and the valves are thicker. The ventral valve is gently to very strongly convex but rarely geniculate. A median sulcus separates well defined visceral humps, and irregular costae are often present on the anterior part. The visceral disk of the dorsal valve is flat with a median fold and is more rectangular in outline than the dorsal valve of *H. horrida*. The surface of both valves has a fine granular sculpture, often obscured by loss of the outer shell layer or by silicification. Spines on the ventral valve are limited to the visceral humps where they occur in one to three or more longitudinal rows. Cardinal and auricular spines are present on the dorsal valve; they vary in number and thickness.

The interior of the valve is similar to that of *H. horrida* but the divaricator muscle impressions are relatively larger and extend anterior to the adductor muscle platform. The interior of the dorsal valve has a median septum extending anterior to the brachial impressions and often reaching the anterior border. In Spitsbergen specimens the posterior half of the dorsal valve is raised and separated from the anterior half by a prominent step. The anterior border is often thickened and bears coarse pustules which may be sharply pointed. The cardinal process is similar in form to that of *H. horrida* but is relatively larger.

Variation. Apart from a single Russian specimen, the only specimens I have seen are from Spitsbergen. These show variation in convexity of the ventral valve, development of the auricles, and number of auricular spines on the dorsal valve. However, these forms occur together at the same horizon. The variation in this species has been noticed by Fredericks (1934) and Stepanov (1936; 1937), both of whom described their specimens as specifically distinct from *H. timanica* Stuck. Fredericks thought (presumably) that the granular sculpture formed the bases of fine spines lying tangential to the surface. He put the species into *Ruthenia* (= *Waagenoconcha*). His three subspecies, *R. granulifera typica*, *R. granulifera gibbosa*, and *R. granulifera spitzbergensis*, parallel Stepanov's *Horridonia borealis granulifera*, *H. borealis borealis*, and *H. borealis granulifera* ab.

auriculata respectively. Stepanov distinguishes between the two subspecies of *borealis* as follows:

borealis	*granulifera*
Ratio of curvature of ventral valve to length of dorsal valve not exceeding 3.	This ratio not exceeding 2.
Auricles strongly arched.	Auricles not strongly arched.
Dorsal valve considerably concave.	Dorsal valve less concave.
Anterior part of ventral valve distinctly costate.	Anterior part of ventral valve non-costate.

Stepanov's subspecies are also more or less equivalent to Dunbar's *rudis* (= *borealis*) and *maynci* (= *granulifera*).

In the Spitsbergen specimens I have studied, all these forms are represented and are connected by transitional types.

Discussion. Toula described this species in 1875 as *Productus horridus* var. *granuliferus*. I have been unable to discover whether he has priority over Stuckenberg 1875. The publishers of Toula's paper have no record of the date of its publication and I have been unsuccessful in tracing the date of publication of Stuckenberg's work. However, Stuckenberg's description and figures are more adequate than those of Toula and it seems justifiable to use Stuckenberg's name. His description is fairly complete but he strongly suggests that cardinal spines are present on the ventral valve and his figures show spine bases in this region (Pl. 5, fig. 10). The only Russian specimen I have seen was kindly lent to me by Professor Dunbar. It was collected by W. Kulien from the river Adz'va, 59° E., 67° N., and identified by Fredericks. This specimen is figured on Pl. 4, fig. 4 *a–c*; there is no trace of cardinal spines on the ventral valve. However, in this specimen and also in specimens from Spitsbergen, opposite each dorsal cardinal spine there is a depression in the rather thin cardinal border of the ventral valve, and between

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EXPLANATION OF PLATE 4

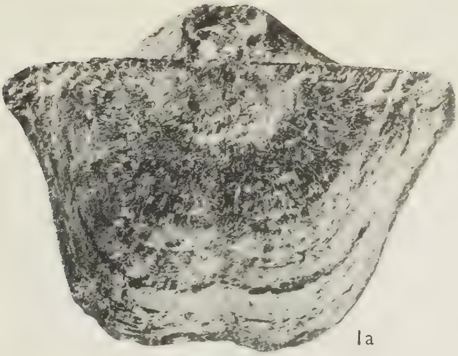
Figs. 1–4. *Horridonia timanica* (Stuckenberg). Natural size. 1*a–c*, Dorsal, ventral and lateral views, S.M. E17817, Limestone A (Spirifer Limestone), Templet, Bunsowland, Spitsbergen. 2*a–c*, Dorsal, ventral and lateral views, S.M. E17832, same locality as fig. 1. 3, Dorsal view, S.M. E17833, same locality as fig. 1. 4*a–c*, Dorsal lateral and anterior views, P.M. S2231, River Adz'va, Bolshezemelskaya Tundra, U.S.S.R., 59° E, 67° N.

EXPLANATION OF PLATE 5

Figs. 1–4. *Horridonia timanica* (Stuckenberg). Natural size. Silicified valves treated with dilute HCl. 1, Ventral valve interior, S.M. E17822, Mertonberget, Ny Friesland, Spitsbergen. 2, Ventral valve interior, S.M. E17517, Limestone A (Spirifer Limestone), Gipshuken, Bunsowland, Spitsbergen. 3, Dorsal valve interior, S.M. E17608*a*, Limestone A (Spirifer Limestone), Tyrellfjellet, Bunsowland, Spitsbergen. 4, Dorsal valve interior, S.M. E17821, same locality as fig. 1.

Figs. 5, 7, 8. *Horridonia horrida* (J. Sowerby). Latex casts from natural internal moulds, Middle Magnesian Limestone, Humbledon Hill Quarry, Sunderland. 5, Reverse view of cardinal process, ×2, B.M. 43384. 7, Ventral valve interior, ×1, B.M. 97553. 8, Dorsal valve interior, ×1, B.M. 43384.

Figs. 6, 9–13. *Horridonia timanica* (Stuckenberg). 6, Reverse view of silicified cardinal process, ×2, S.M. E17823, Mertonberget, Ny Friesland, Spitsbergen. 9–12, Reproduction of original figures of *Productus timanicus* Stuckenberg 1875, pl. 1. figs. 1, 4, 2*a*, 2*c*, 9, Ventral valve anterior. 10, Ventral valve suggesting presence of cardinal spines (see discussion in text). 11, Dorsal valve interior. 12, Dorsal valve exterior. 13*a–c*, Reproduction of original figures of *Productus horridus* Sow. var. *granuliferus* Toula 1875, pl. 6, figs. 3 *a–c*. *a*, Ventral view. *b*, Lateral view. *c*, Part of the shell surface, magnified.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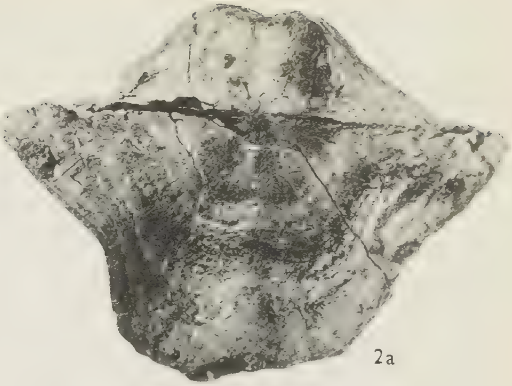
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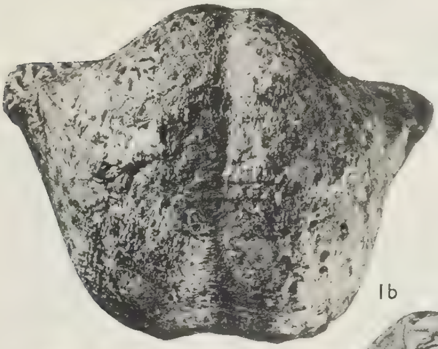
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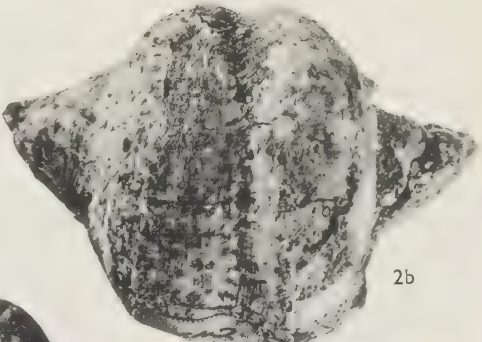
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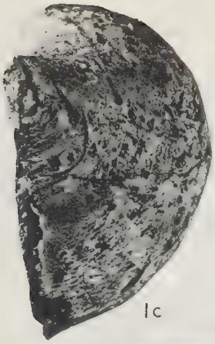
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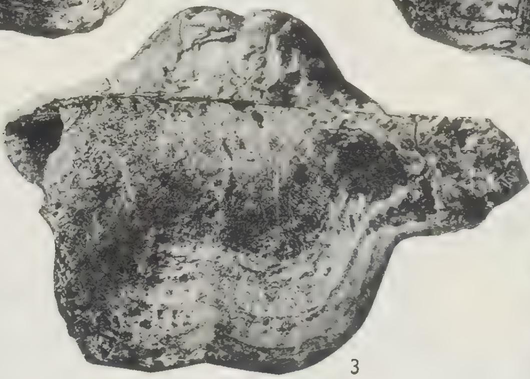
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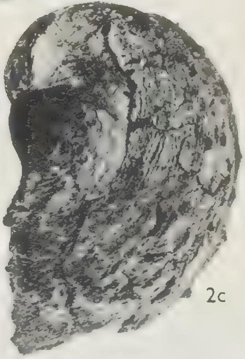
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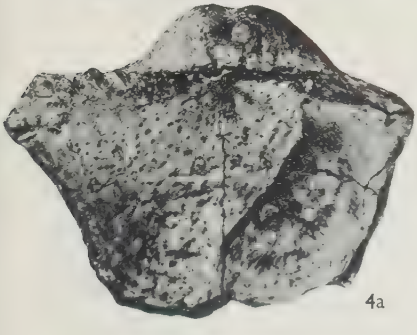
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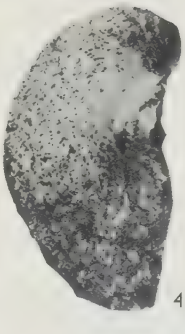
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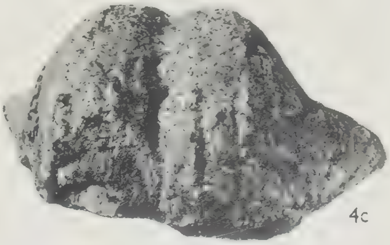
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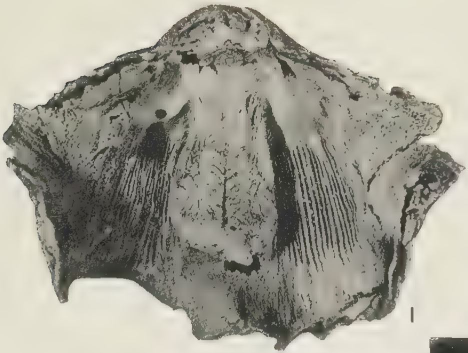
GOBBETT, *Horridonia timanica*, × 1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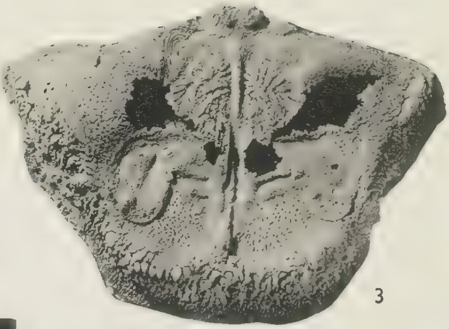
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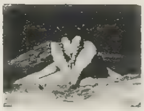
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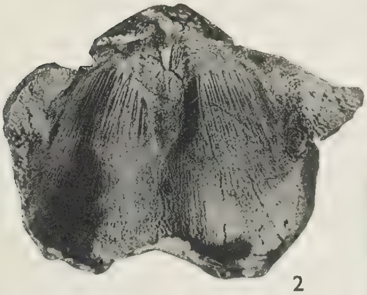
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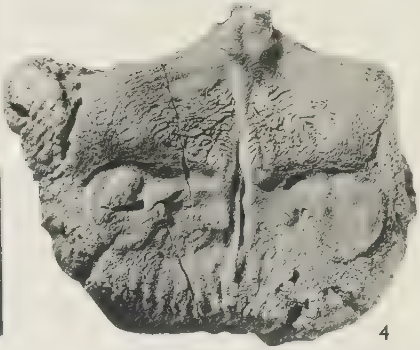
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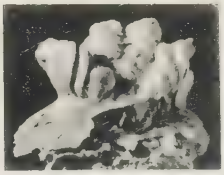
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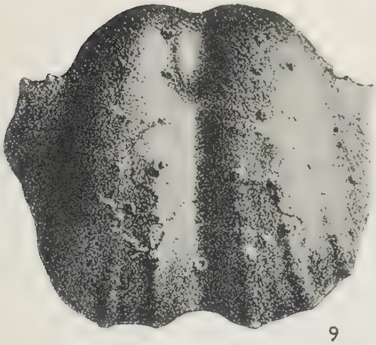
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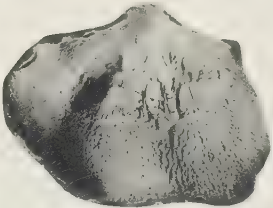
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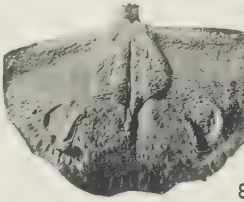
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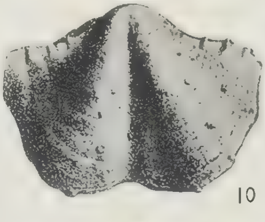
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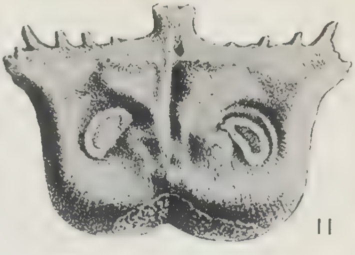
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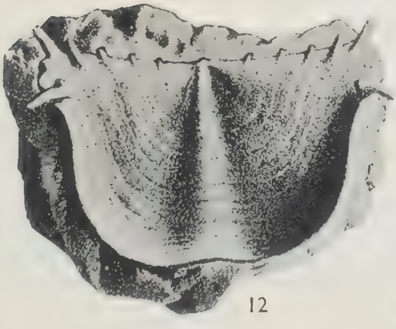
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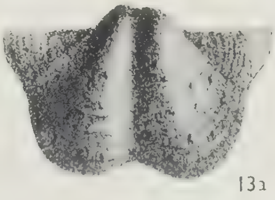
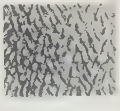

13a

13b


13c

CORBETT *Herridonia*

these depressions the relatively raised shell simulates spine bases. I assume that Stuckenberg mistook these for spine bases.

This species has long been known from Spitsbergen and Russia where its occurrence, along with other Productids and Spiriferids, was taken to indicate an Upper Carboniferous (Uralian) horizon in the sense of Tschernyschew (1902). The Nearctic forms were also referred to *H. timanica* by Tschernyschew and Stepanov (1916), Grönwall (1917), and Frebold (1931; 1942; 1950) and the strata containing them were thought to be equivalent in age to the Schwagerinakalk. Stepanov (1936; 1937) considered that the Spitsbergen specimens were intermediate between *H. timanica* and *H. horrida* and indicated an age intermediate between that of the Schwagerinakalk and the Zechstein. He referred them to *Productus* (*H.*) *borealis* Haughton.

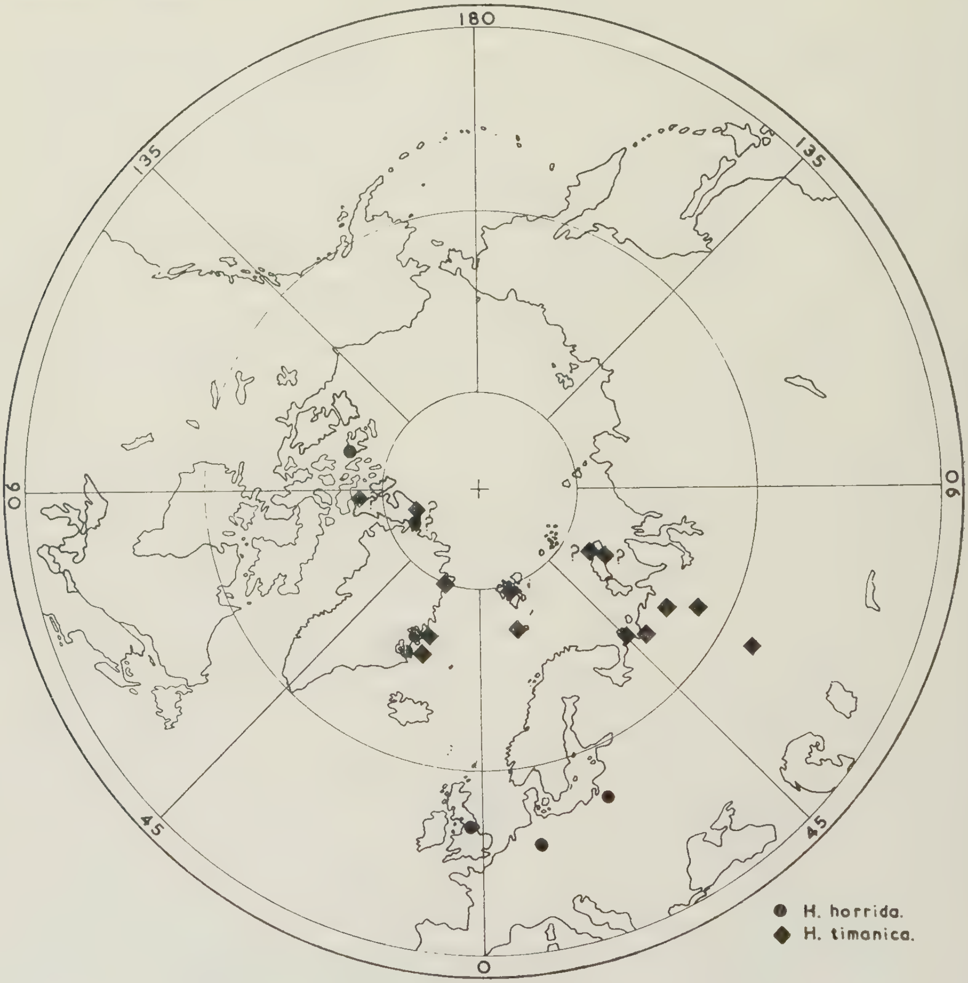
Frebold (1942) discussed the whole question of the age of the Arctic Permian brachiopod faunas and concluded that they corresponded to the Sakmarian and Artinskian brachiopods of the Timan and the Urals. He recognized the variation in the Arctic *H. timanica* but included the varieties in this species and criticized Stepanov's use of Haughton's poorly known species *borealis*. Finally Dunbar (1955) decided to make a fresh start and erected two new species, *maynci* and *rudis*, for the Greenland forms, both of which he identified with Spitsbergen forms.

Distribution (text-fig. 1). Tschernyschew (1902) records *H. timanica* from the Timan as rare in the Korallen- and Omphalotrochuskalk but common in the Cora and Schwagerina horizons above. In the Urals it is restricted to the Cora horizon but on the River Ai, on the Ufa plateau (55° 35′ N. 58° 30′ E), it is found in the Kalk Dolomite horizon CPc. Wiman (1914), Stepanov (1936; 1937), and Frebold (1937) describe it from the Spirifer Limestone of Spitsbergen and Bear Island. It is also found in the Brachiopod Cherts above the Spirifer Limestone (= 1st A) in Central Vestspitsbergen. Fredericks (1934) records it from the Kanin Peninsula in the valley of the River Nottey, presumably in the small outcrop of Permian strata at about 67° 45′ N. 45° 40′ E. (1956 Geological Map of the U.S.S.R., Ed. D. V. Nalivkin). *H. timanica* also occurs in the 'Productus Limestone' of central east Greenland (Frebold 1931; Dunbar 1955) and in Amdrups Land and Holms Land in north-east Greenland (Grönwall 1917; Frebold 1950).

The presence of this species in other parts of the Arctic is less certain. The specimens from Novaya Zemlya (Licharew and Einor 1939) are rather poorly figured; the general form of the shell is like that of *Horridonia* and the whole surface appears to have a granular sculpture but the cardinal spines are obscure. They were collected from two areas in the North Island, one in the Russian Harbour–Pankratiev Peninsula region and the other on the east coast near Cape Spory Na'volok (76° 15′ N. 68° 15′ E.). Those specimens described by Tschernyschew and Stepanov (1916) are all young shells, collected from Great Bear Cape, King Oscar's Land, about 77° 35′ N. 88° W. Whitfield described specimens, some of which may be *H. timanica*, from Cape Sheridan at 82° 27′ N. on Ellesmere Island.

In the past, the formations from which *H. timanica* has been obtained have been referred either to the Carboniferous or to the Permian. This depended on whether the rest of the fauna, largely of brachiopods, appeared to have Carboniferous or Permian affinities. Many of these brachiopods are probably facies fossils. Tschernyschew's Cora and Schwagerina horizons are now considered Sakmarian to Lower Artinskian. The

Omphalotrochuskalk may belong to the Upper Carboniferous, *Triticites* Zone (Dunbar 1940) and L. C. Librovich (1958) puts it in the Gschelian, i.e. middle Upper Carboniferous. The Spirifer Limestone of Spitsbergen lies about 500 metres above the base of the Permian (Forbes, Harland, and Hughes 1958). The age of this formation is controversial: Stepanov (1957) makes it equivalent to the Russian Kungurian. Dunbar (1955) considers the east Greenland Permian to be of Zechstein age.



TEXT-FIG. 1. Distribution of *H. horrida* and *H. timanica*.

The time-range of *H. timanica* thus extends from Upper Carboniferous to Upper Permian.

DOUBTFUL SPECIES OF *HORRIDONIA*

1. *Horridonia texana* King (1930, p. 85, pl. 21, figs. 25*a–c*). This species is based on a single specimen. According to King it is distinguished by its deeper sinus and triangular,

rather than pentagonal outline. It occurs in the Middle Word formation of the Glass Mountains. The material is obviously insufficient on which to base a new species. The figures show that only the posterior part of the ventral valve is preserved. This is silicified and no surface sculpture is visible.

2. '*Productus*' *pseudohorridus* Wiman (1914, p. 74, pl. 17, figs. 1–11). *P. pseudohorridus*, which has a long synonymy and which appears to be widespread in the Arctic Permian, differs from *Horridonia* in the distribution of spines and in the internal character of the dorsal valve. The smaller of Haughton's two syntypes of *P. sulcatus* var. *borealis* is probably this species.

3. '*Productus*' *pseudotimanicus* Gerassimov (1934, p. 404). Gerassimov (1952) described two forms of his species, *typica* and *depressa*. The figured specimens are all internal moulds. The illustrations are poor but the moulds appear to be conspecific with *Horridonia timanica* (Stuckenberg). I am indebted to Professor D. L. Stepanov of Leningrad University for a photocopy of the relevant part of Gerassimov's 1952 paper.

4. *Horridonia mitis* Hill (1950, p. 17, pl. 8, figs. 7–10, pl. 9, fig. 1). Only the ventral valve has been described and the distribution of the cardinal spines is not clear. In size and shape this species resembles '*P.*' *pseudohorridus* Wiman, but it differs in the distribution of the visceral spines.

Acknowledgements. I am indebted to Mr. J. S. Jackson of the National Museum of Ireland for the loan of Haughton's syntypes of *Productus sulcatus* var. *borealis*; Professor C. O. Dunbar of Yale University for the loan of a Russian specimen of *Horridonia timanica*, for supplying me with a translation of Stuckenberg's original description of that species and a copy of the original figures; Dr. H. M. Muir-Wood of the British Museum (Natural History) for the loan of specimens of *H. horrida*, for supplying me with photographs of the lectoype of that species, for reading the manuscript and giving much helpful advice; Mr. W. B. Harland of this department for suggesting this study and making available Spitsbergen *H. timanica*; Dr. K. S. W. Campbell of University of New England, Armidale, for general advice and encouragement; Dr. M. J. S. Rudwick of this department for aiding me in matters of terminology and presentation; Mr. A. Barlow of this department for the photography; and Miss M. Potts for typing the manuscript. The work was carried out during the tenure of a D.S.I.R. Research Studentship.

Repositories. B.M.—British Museum (Natural History). S.M.—Sedgwick Museum, Cambridge. P.M.—Peabody Museum, Yale University.

REFERENCES

BRANSON, C. C. 1948. Bibliographic Index of Permian Invertebrates. *Mem. Geol. Soc. Amer.* **26.**

CHAO, Y. T. 1927. Productidae of China, Part 1. *Palaeont. sinica*, B, **5,** fasc. 2, 1–192.

—— 1928. Productidae of China, Part 2. Ibid. **5,** fasc. 3, 1–81.

DUNBAR, C. O. 1940. The Type Permian: its Classification and Correlation. *Bull. Amer. Ass. Petrol. Geol.* **24,** 237–81.

—— 1955. Permian Brachiopod Faunas of Central East Greenland. *Medd. Grønland*, **110,** no. 3, 1–169, pl. 1–32.

EISEL, R. 1909. Ueber die Varianten des *Productus horridus* Sowerby, bei Gera. *Jber. Ges. Fr. Naturw. Gera*, 49–50, 33–37, fig. 1–10.

FORBES, C. L., HARLAND, W. B., and HUGHES, N. F. 1958. Palaeontological Evidence for the Age of the Carboniferous and Permian Rocks of Central Vestspitsbergen. *Geol. Mag.* **95,** 469–90.

FREBOLD, H. 1931. Das Marine Oberkarbon Ostgrönlands. *Medd. Grønland*, **84,** no. 2, 1–88, pl. 1–6.

—— 1933. Weitere Beiträge zur Kenntnis des Oberen Paläozoikums Ostgrönlands. *Medd. Grønland*, **84,** no. 7, 1–61, pl. 1–6.

—— 1937. Das Festungsprofil auf Spitzbergen, 4, Die Brachiopoden- und Lamellibranchiatenfauna und die Stratigraphie des Oberkarbons und Unterperms. *Skr. Svalb. og Ishavet*, **69,** 1–85, pl. 1–11.

FREBOLD, H. 1942. Über die Productiden des Brachiopodenkalkes. *Skr. Svalb. og Ishavet*, **84,** 1–68, pl. 1–4.

—— 1950. Stratigraphie und Brachiopodenfauna des Marinen Jungpalaeozoikums von Holms und Amdrups Land (Nordostgrönland). *Medd. Grønland*, **126,** no. 3, 1–97, pl. 1–6.

FREDERICKS, G. 1915. Notes Paléontologiques. 1. Sur les Productus du Carbonifère supérieure et de l'Artinskien. *Mém. Com. Géol., St.-Pétersb.*, N.S. **103,** 1–63, pl. 1–5.

—— 1928. Contribution to the classification of the genus *Productus*. *Bull. Com. geol. U.S.S.R.* **46,** 773–92.

—— 1934. The Permian Fauna of the Kanin Peninsula. *Trans. arct. Inst., Leningr.* **13,** 5–42, pl. 1–5.

GEINITZ, H. B. 1861. *Dyas, oder die Zechsteinformation und das Rothliegendes.* **1,** Leipzig.

GERASSIMOV, N. P. and TIKHVINSKAYA, E. I. 1934. The classical section of the Kungur Deposits; results of the research carried out in 1931. *Rec. Russ. miner. Soc.* **63,** 390–440.

GERASSIMOV, N. P. *et al.* 1952. Productids of the Kungurian and Artinskian deposits of Molotovsk, Pre-Urals. *Trans. Nat. Sci. Inst. Molotovsk State Univ.* **10,** parts 3, 4.

GIBSON, W. and WEDD, C. B. 1913. The Geology of the Northern Part of the Derbyshire Coalfield and bordering tracts. *Mem. geol. Surv. U.K.*

GRÖNWALL, K. A. 1917. The marine Carboniferous of north-east Greenland and its brachiopod fauna. *Medd. Grønland*, **43,** no. 20, 511–618, pl. 27–29.

HAUGHTON, S. 1858. Geological notes and Illustrations in McClintock, F. L. Reminiscences of Arctic Ice Travel in search of Sir John Franklin and his Companions. *J. Roy. Soc. Dublin*, **1,** 239–50, pl. 5–11.

HILL, D. 1950. The Productinae of the Artinskian Cracow fauna of Queensland. *Queensland Univ. Dept.* Geol. Papers, **3,** no. 2.

HOWSE, R. 1848. A catalogue of the fossils of the Permian system of the counties of Northumberland and Durham. *Trans. Tyneside Naturalists' Field Club*, **1,** 219–64.

KING, R. E. 1930. Geology of the Glass Mountains, Texas, Pt. 2. *Bull. Univ. Tex.* **3042.**

KING, W. 1848. *A Catalogue of the Organic Remains of the Permian Rocks of Northumberland and Durham.* Newcastle upon Tyne.

—— 1850. A Monograph of the Permian Fossils of England. *Palaeontogr. Soc.*

KONINCK, L. DE. 1846. Monographie du Genre Productus. *Mém. Soc. Sci. Liége*, **4,** 71–278.

LIBROVICH, L. C. 1958. Carboniferous System, *in Geological Formations of the U.S.S.R.*, 1, *Stratigraphy*, Ed. Ovechkin, N. K. 306–44.

LICHAREW, B. K. and EINOR, O. L. 1939. Paleontology of the Soviet Arctic, Part 4. Contributions to the Knowledge of the Upper Paleozoic fauna of Novaya Zemlya, Brachiopoda. *Trans. arct. Inst. Leningr.* **127,** 1–245.

MALZAHN, E. 1937. The German Zechstein Brachiopoda. *Abh. preuss. geol. Landesanst.*, N.S. **185.**

MUIR-WOOD, H. M. and COOPER, G. A. 1960. Morphology, classification, and life-habits of the Productoidea (Brachiopoda). *Mem. Geol. Soc. Amer.* **81.**

SCHUCHERT, C. and LEVENE, C. M. 1929. Brachiopoda (Generum et Genotyporum Index et Bibliographia). *Fossilium Catalogus, 1, Animalia*, **42,** 1–140.

SOWERBY, J. 1823. *The Mineral Conchology of Great Britain*, **4,** London.

SOWERBY, J. DE C. 1829. Idem. **6,** London.

STEPANOV, D. L. 1936. Contribution to the Knowledge of the brachiopod fauna of the Upper Paleozoic of Spitsbergen. *Ann. Leningr. Univ. Geol.-Geogr. series*, **2,** 114–28, pl. 1–5.

—— 1937. Permian Brachiopods of Spitsbergen. *Trans. arct. Inst., Leningr.* **76,** 105–92, pl. 1–9.

—— 1957. A new stage of the Permian in the Arctic. *Messenger of Leningrad University*, **24,** *Geol. and Geogr. ser.* **4,** 21–24.

—— 1959. Brachiopods of the Lithuanian Zechstein. *Ann. Leningr. Univ.* **268,** *Geol. Sci. ser.* **10,** 190–207.

STUCKENBERG, A. 1875. Report on a geological voyage to the Petschora Land and the Timan Tundra. *Collections to the Geology of Russia*, **6,** 1–126. (Edited by Imp. St. Petersburg Min. Soc.)

THOMAS, I. 1914. The British Carboniferous Producti. I. Genera *Pustula* and *Overtonia*. *Mem. geol. Surv. U.K. Palaeontology*, **1,** 197–366, pl. 17–20.

TOULA, F. 1875. Permo-Karbon-Fossilien von der Westküste von Spitzbergen. *Neues Jb. Min. Geol. Paläont.* 225–64, pl. 5–10.

TSCHERNYSCHEW, T. 1902. Die Oberkarbonischen Brachiopoden des Ural und des Timan. *Mém. Com. géol., St.-Pétersb.* **16,** no. 2.

—— and STEPANOV, P. 1916. La Faune du carbonifère supérieure de la Terre du Roi Oscar et de la Terre de Heiberg. *Mater. Geol. Russld.*, **27,** 1–105, pl. 1–12.

TRECHMANN, C. T. 1925. The Permian Formation in Durham. *Proc. Geol. Assoc.* **36,** 135–45.

WATSON, WHITE. 1811. *A Delineation of the Strata of Derbyshire forming the Surface from Bolsover in the East to Buxton in the West.* Sheffield.

WHITFIELD, R. P. 1908. Notes and observations on Carboniferous fossils and semi-fossil shells, brought home by members of the Peary expedition of 1905–6. *Bull. Amer. Mus. nat. Hist.* **24,** 51–58, pl. 1–4.

WIMAN, C. 1914. Über die Karbonbrachiopoden Spitzbergens und Beeren Eilands. *Nova Acta Regiae Societatis Scientiarum Upsaliensis* (4), **3,** no. 8, 1–91.

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NEW NAMURIAN GONIATITES OF THE GENUS *EUMORPHOCERAS*

by PATRICIA J. YATES[1]

ABSTRACT. Two new species of Carboniferous goniatites, *Eumorphoceras rota* and *E. medusa* and a variety, *E. medusa* var. *sinuosum*, are described from the *Cravenoceras leion* zone on Slieve Anierin, Co. Leitrim, Ireland.

THESE new forms were collected from the *Cravenoceras leion* Zone (E_{1a}) on Slieve Anierin, Co. Leitrim, Ireland, during an investigation of the Namurian faunas of the area. *Eumorphoceras rota* is the earlier of the new species and occurs with typical *Eumorphoceras pseudocoronula* Bisat. *Eumorphoceras medusa* and *E. medusa* var. *sinuosum* are both found in later deposits which are, however, still within the *Cravenoceras leion* Zone. They are considered to show the later stages in the evolution of *E. pseudocoronula*. An example of the latter (occurring on the same level as *E. rota*) is figured (Pl. 6, fig. 3) to illustrate the lines along which evolution has proceeded to result firstly in the species *E. medusa* and then in the probably slightly later variety, *E. medusa* var. *sinuosum*.

Eumorphoceras medusa sp. nov.

Plate 6, figs. 1, 2.

Synonymy. Poorly preserved specimens of this species may in the past have been referred to *Eumorphoceras pseudocoronula* Bisat (1950, p. 19, pl. 2, fig. 4).

Description. The adult individuals are platyconic, with the last whorl high. On the same slab as the holotype a young individual of 10 mm. diameter appears to be a less flattened form with less difference between whorl height and whorl thickness. There are strong constrictions which in the holotype number six in half a whorl. These constrictions show a forward bow close to the umbilical edge; over the flanks they are slightly concave before curving forward to end at the latero-ventral groove with a strongly defined termination. Between these constrictions the ornament consists of muted plications which persist across the flanks. The shoulder furrow is divided by a broad flattened ridge but the resulting ventro-lateral furrow is very faint. The latero-ventral furrow is shallow but still persistent at the largest diameter seen. The umbilicus is open but not large and has a raised rim around its edge.

The very early stages are not well seen. At about 10 mm. the constrictions leave the umbilicus radially and arch smoothly forward to a salient at the shoulder [St. Ri. 2. 23 (Pl. 6, fig. 2) and St. Ri. 2. 26]. A weak beading of the umbilical edge can be seen at these early diameters [see the early part of St. Ri. 2. 23 (Pl. 6, fig. 2)]. With increasing diameter all indications of the umbilical beading disappear and the constrictions begin to develop the forward bow close to the umbilical edge. At large diameters the con-

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[1] Miss Yates died on 7 August 1960 while this paper was in the press.

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strictions become less strongly incised over the flanks and the actual terminations are less distinct than the earlier definite end at the latero-ventral groove.

Holotype. Doh. 6B. 10 (part and counterpart, Pl. 6, fig. 1). *Paratypes*. Doh. 6B. 14, St. Ri. 2. 24 (part and counterpart). Doh. 6B. 7, St. Ri. 2. 25, St. Ri. 2. 23 (Pl. 6, fig. 2). *Dimensions*. Doh. 6B. 10: diameter *c*. 21 mm., umbilical diameter 3·5–4 mm. Doh. 6B. 14: diameter *c*. 23 mm. St. Ri. 2. 23: diameter *c*. 10 mm. The other paratypes are too incomplete to allow exact measurements but appear to approximate to the above figures. The specimens are in the author's collection in the Murchison Museum, Department of Geology, Imperial College, London. The form is reasonably common and the material examined includes many incomplete specimens.

Type locality. The material on which this new species is based was collected from the mountain of Slieve Anierin, Co. Leitrim, Ireland. Locality Doh. 6 is on Irish Ordnance Survey 6-inch sheet Leitrim 21 (14) and lies about 150 yards beyond the last field boundary on the east bank of the stream which flows to the east of the old coal-mine track. The section consists of about 30 feet of light-brown shales and the goniatites were collected about 20 feet above the base.

Locality St. Ri. 2 is on 6-inch sheet Leitrim 20 (8) and lies on the south bank of the Stony River; the section consists of a sheer cliff about 40 feet high and the fossils were all collected within a few feet of the base of the section.

Horizon. At both localities *E. medusa* is associated with *Pseudamussium* cf. *praetenuis* (von Koenen), *Kazakhoceras sp*. with a beaded venter, and *Posidonia trapezoedra* Ruprecht. The horizon is about 25 feet above an horizon rich in *Cravenoceras leion* Bisat and *Eumorphoceras pseudocoronula* Bisat.

Discussion. *E. medusa* is closely related to *E. pseudocoronula* Bisat, but differs markedly in the absence of the intermediate ribs between the constrictions. These intermediate ribs were observed to occur in examples of Bisat's species from the horizon 25 feet below the type horizon. An example of *E. pseudocoronula* is figured here (Pl. 6, fig. 3) from the lower faunal band on Slieve Anierin. Both sides of the constrictions are usually raised into sharp rib-like edges and there are in addition two intermediate short ribs between the constrictions. These ribs fade some distance before the ventro-lateral groove. The umbilical edge is raised and beaded by the ribs. There is a groove on both sides of the shoulder ridge but the more ventral groove is less strong.

The stratigraphically higher *E. medusa* therefore differs from the lower *E. pseudocoronula* Bisat in that the short ribs beading the umbilical edge have been lost. The edge of the umbilicus is raised into a rim but is never beaded in the adult stage in *E. medusa* and the ornament between the constrictions consists of gentle plications which apparently persist across the flanks. The umbilicus is smaller in *E. medusa* than in *E. pseudocoronula*, and the ventral furrow has become almost non-existent in the former. The forward bowing of the constrictions near the umbilical edge and fine plications in the region of the umbilicus in *E. medusa* are likewise distinguishing features which are absent in *E. pseudocoronula*.

Miller and Furnish (1940, pp. 364–6, pl. 47, figs. 6–12) describe and figure *Girtyoceras limatum* (Miller and Faber), which, judging from the plates, resembles *E. medusa*. The specimens are all internal moulds, the external form has not been seen, and the zonal position is too imprecise for exact correlation. The evidence is not sufficiently strong to prove identity with *E. medusa*.

The Geological Survey specimen Ca. 4782 (from a stream in Bowland Shales 40 feet above the lowest *Cravenoceras leion* beds in Bateson Wood, 550 yards north-east of Crag House, Yorkshire) is here assigned to *E. medusa*. Bisat had previously identified this specimen as *E.* aff. *hudsoni* Gill but had commented on the label about the umbilical bowing and considered that it might be a new form.

Eumorphoceras medusa var. *sinuosum* var. nov.

Plate 6, figs. 4, 5

Description. The adult individuals are platyconic with the last whorl high. The young individuals are less flattened. In the adult form there are several sinuous constrictions which have a strong forward bowing close to the umbilicus. They are more strongly incised in this region than over the rest of the flank, where they become less strong as they curve forward to the latero-ventral groove. Between the constrictions there are frequent fine ribs or plications which pass over the flanks and can be seen on the shoulder ridge and on the venter. The latero-ventral groove persists but the ventro-lateral groove is scarcely visible. The umbilicus is relatively small, the edge slightly raised. Several specimens show rather strong spiral striae on the latero-ventral ridge.

Holotype. Agh. 8. 1 (Pl. 6, fig. 4). *Paratypes.* Agh. 8. 2 (Pl. 6, fig. 5), Agh. 8. 4, Agh. 8. 10. Since no complete specimen has been observed it is not possible to give precise dimensions; they do not appear, however, to differ particularly in this respect from *E. medusa* sp. nov. All these specimens and several others are in the author's collection in the Murchison Museum, Department of Geology, Imperial College, London.

Type locality. Locality Agh. 8, Slieve Anierin, County Leitrim, Ireland, is on Irish Ordnance Survey 6-inch Series Leitrim 23 (4). It is the last accessible exposure of shale along the east side of the stream before the bridge, and is about 20 feet high. The bridge is not marked on the map but the road along which it lies appears to begin near B.M. 272. 1 on Leitrim 23 (8). This variety has also been seen, very rarely, at locality St. Ri. 2, associated with *E. medusa* (St. Ri. 2. 22*a*).

Horizon. The material occurs about 25–30 feet above an horizon rich in *Cravenoceras leion* Bisat and *Eumorphoceras pseudocoronula* Bisat. The horizon is probably slightly higher than that in which *E. medusa* occurs.

Discussion. This is a variant of *E. medusa* which can be distinguished by the larger number of constrictions, which are strongly incised close to the umbilicus but more subdued over the rest of their course to the latero-ventral groove. As a result of the more strongly developed forward bow at the umbilical edge the constrictions have a more sinuous appearance than in *E. medusa*. The spiral ornament on the latero-ventral ridge is particularly strong in this variety.

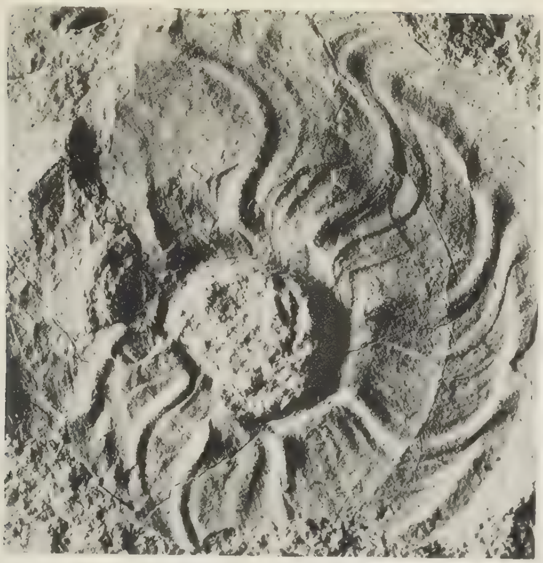
EXPLANATION OF PLATE 6

Figs. 1, 2. *Eumorphoceras medusa* sp. nov., Slieve Anierin, Co. Leitrim, Ireland. 1, Holotype (Doh. 6B. 10), external impression, ×4. 2, Paratype (St. Ri. 2. 23), external impression of an adolescent stage, ×7·3.

Fig. 3. *Eumorphoceras pseudocoronula* Bisat, Slieve Anierin, Co. Leitrim, Ireland. Agh. 21. 3 is shown here as a typical example of the earlier *E. pseudocoronula* to compare with the later species and variety. One fragment is seen as an impression, the other as a mould, ×3.

Figs. 4, 5. *Eumorphoceras medusa* var. *sinuosum* var. nov. Slieve Anierin, Co. Leitrim, Ireland. 4, Holotype (Agh. 8. 1), external mould, ×4½. 5, Paratype (Agh. 8. 2), external mould, ×4¼.

Figs. 6, 7. *Eumorphoceras rota* sp. nov., Slieve Anierin, Co. Leitrim, Ireland. 6, Holotype (Agh. 21. 3), external impression, ×4½. 7, Paratype (Doh. 50. 1), external mould, ×4½.



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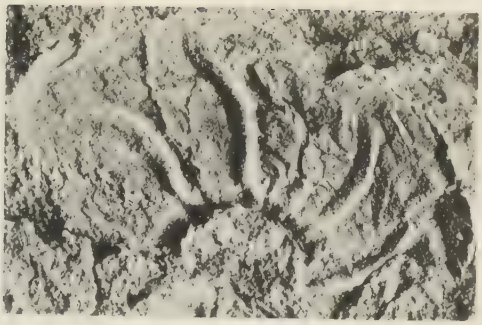

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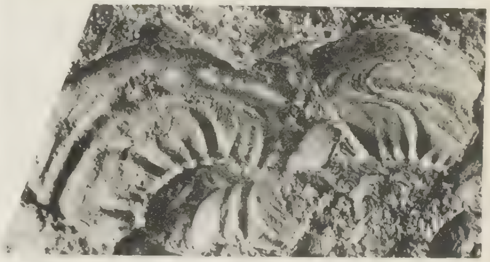

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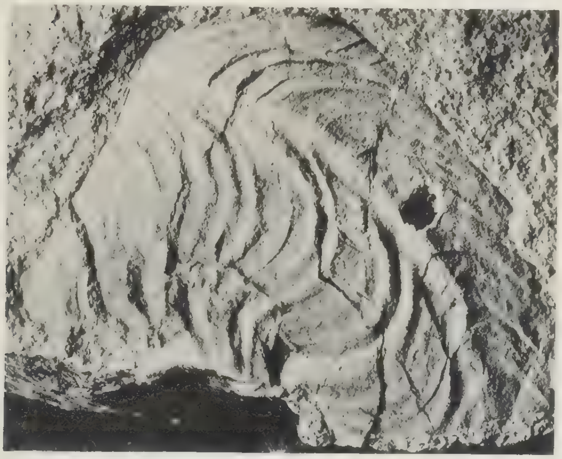

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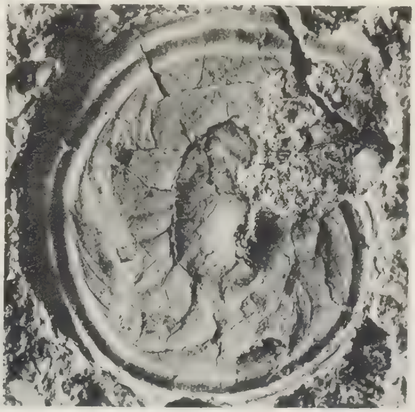

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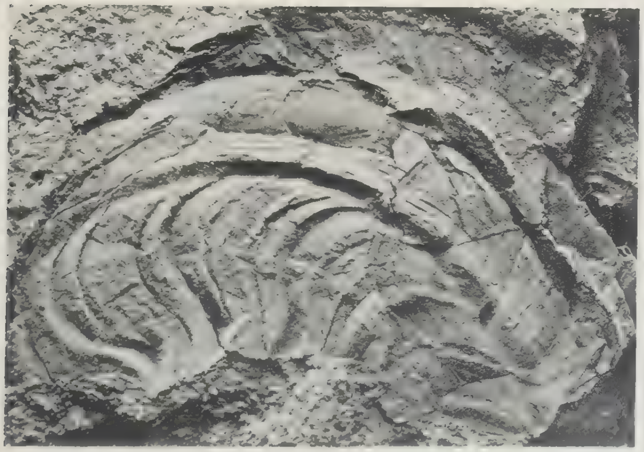

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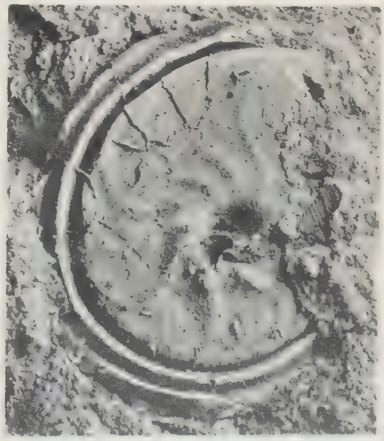

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Elias (1956, pp. 132–3) erected a new subgenus of *Eumorphoceras* which he named *Edmooroceras* in honour of E. W. J. Moore, and included *E. pseudocoronula* in this group. This subgenus is distinguished by 'a sub-angular and noduse umbilical edge; a more discoidal conch; a greater flattening of the venter in youthful and subadult stages; and a very narrow and low ventral carina, sharply rising upon the flattened venter at these same stages'. At least in the young forms *E. medusa* has a nodose umbilical edge and is closely related to *E. pseudocoronula*. The type species of *Edmooroceras* is *E. plummeri* Miller and Youngquist which, however, judging from the description and plates given by these authors (1948, pp. 665–7, pl. 100, figs. 1–4, 20, 21) does not resemble *E. pseudocoronula*, *E. medusa*, or *E. medusa* var. *sinuosum*. I prefer to retain these species as *Eumorphoceras* and not to place them in *Edmooroceras* as the type species of the latter is similar to *E. bisulcatum* Girty and is a strongly ribbed form and apparently without constrictions. Miller and Youngquist (1948, p. 666) comment that the type specimens of *E. plummeri* appear to resemble closely the form figured by Moore (1946, pl. 22, fig. 3). This specimen is in fact *E. bisulcatum* Girty, s.l., from Sabden Shales, near Samlesbury Bottoms, River Darwen, Lancashire, and is from the *Nuculoceras nuculum* subzone of E_2 age. It seems questionable, therefore, whether *E. pseudocoronula* should be placed in the subgenus *Edmooroceras*.

Eumorphoceras rota sp. nov.

Plate 6, figs. 6, 7

Description. Adult individuals platyconic. The umbilicus is minute. The shoulder groove is divided into two furrows of equal strength by a strong, rounded ridge. The ornament consists of extremely subdued sickle-shaped striae with a well developed ventro-lateral salient. Periodically there appears to be a stronger plication of the surface, a feature seen faintly on the external impression Agh. 21. 3, where there are about five or six of these per quarter whorl. This feature is also seen on the external mould Doh. 50. 1.

Holotype. Agh. 21. 3: diameter 12 mm. (Pl. 6, fig. 6). *Paratypes.* Doh. 50. 1: diameter 12 mm. (Pl. 6, fig. 7). Agh. 21. 4: diameter 11 mm. The material, which consists of about twelve specimens, is in the author's collection in the Murchison Museum, Department of Geology, Imperial College, London. All the specimens are external impressions and show no sutures.

Type locality. The material was collected from two localities on Slieve Anierin, Co. Leitrim, Ireland. Locality Agh. 21 is on Irish Ordnance Survey 6-inch sheet Leitrim 24 (1) on the west side of the stream running to the west of B.M. 801. 1 at the point where the 800-foot contour crosses the stream.

Locality Doh. 50 is on 6-inch sheet Leitrim 21 (14) on the west of the stream which flows to the east of the old coal-mine track, and is almost due east of B.M. 1249. 8 on this same track.

Horizon. Both localities are considered to be low in E_1. *E. rota* is associated with *E. pseudocoronula* Bisat and *Cravenoceras leion* Bisat.

Discussion. E. rota is easily distinguished by its minute umbilicus, the marked prominence of the shoulder ridge and the subdued nature of the ornament. The sinuous nature of the ornament is reminiscent of that in *Eumorphoceras* sp. form A. (Moore 1946, pp. 418–19, pl. 25, fig. 2), but the latter has a much larger umbilicus, stronger ornament, and a less prominent shoulder ridge. *Eumorphoceras tornquisti* (Wolterstorff) is considered by Bisat (1950, pp. 20–21, pl. 2, fig. 2) to be very similar and possibly identical with *E.* sp. form A. Moore and like the latter is therefore easily distinguished from *E. rota. Girtyoceras? costatum* (Ruprecht), figured by Bisat (1950, pl. 1, fig. 6) and also by Ruprecht (1937, pp. 271–2, pl. 10, figs. 5, 6) as *Sagittoceras costatum*, is similar in having a minute umbilicus. However, Ruprecht's description mentions only a deep furrow at the shoulder and the form has a much sharper ornament. It is also usually associated with *Lyrogoniatites georgiensis* Miller and Furnish and therefore occurs on a lower horizon than *E. rota.*

Rayner (1953, p. 286) refers to *Girtyoceras? costatum* Ruprecht (G.S.M. 85050) from a boring at Mount Pleasant, one mile south-west of Barnard Castle, Yorkshire. This specimen has been examined and although rather indistinct in the region of the groove there is definitely no strong ridge and the ornament is much stronger than that of *E. rota.* This specimen is very similar to the better specimen from the Alport Boring Zl 4707 (figured by Bisat 1950, pl. 1, fig. 6) and is distinct from *E. rota.*

There is, however, at the Geological Survey a specimen (84690) collected from Little Mearley Clough, Pendle, by E. W. J. Moore which has been identified as *E. pseudocoronula* Bisat. Associated with this species there is an unidentified form which is now believed to be *E. rota*. I am indebted to Mr. Bisat who had previously noted this form and informed me of its existence on seeing examples of *E. rota.*

Acknowledgements. I am indebted particularly to Mr. W. S. Bisat who has given me much advice and assistance in preparing this paper; also to Dr. Gwyn Thomas for advice during its preparation, and to Mr. M. Mitchell who provided me with easy access to Geological Survey material.

REFERENCES

BISAT, W. S. 1950. The junction faunas of the Viséan and the Namurian. *Trans. Leeds Geol. Ass.* **6,** 10–26, pl. 1, 2.

ELIAS, M. K. 1956. Upper Mississippian and Lower Pennsylvanian formations of south-central Oklahoma. *In* Petroleum Geology of Southern Oklahoma, *Amer. Ass. Petrol. Geol.* 56–134.

MILLER, A. K. and FURNISH, W. M. 1940. Studies of Carboniferous ammonoids. *J. Paleont.* **14,** 356–77, pl. 45–49.

MILLER, A. K. and YOUNGQUIST, W. 1948. The cephalopod fauna of the Mississippian Barnett Formation of central Texas. Ibid. **22,** 649–71, pl. 94–100.

MOORE, E. W. J. 1946. The Carboniferous goniatite genera *Girtyoceras* and *Eumorphoceras*. *Proc. Yorks. Geol. Soc.* **25,** 387–445, pl. 22–27.

RAYNER, D. 1953. The Lower Carboniferous rocks in the north of England: a review. *Proc. Yorks. Geol. Soc.* **28,** 231–315, pl. 19.

RUPRECHT, L. 1937. Die Biostratigraphie des obersten Kulm in Sauerlande. *Jahrb. preuss. geol. Landesanst.* **57,** 238–83, pl. 9–10.

LOWER CARBONIFEROUS GASTROPOD FAUNAS FROM OLD CANNINDAH, QUEENSLAND

by W. G. H. MAXWELL

ABSTRACT. Gastropod faunas from Old Cannindah are the lowest found in a Lower Carboniferous sequence of strata, beginning with calcareous subgreywacke and detrital limestones and terminating with reef limestones. Rich faunas of molluscs, brachiopods, and corals occur throughout. The gastropod faunas include one new genus *Austroworthenia*, and six new species, as well as an indeterminate one—*Euphemites minutus*, *Waagenella microstriata*, *Straparolus australis*, *S. subdionysii*, *Austroworthenia levis*, *Loxonema lamellosa*, and *Phymatifer* sp. indet. The species have strong affinities with European forms of late Tournaisian–early Viséan age.

INTRODUCTION

THE present work deals with two small gastropod faunas, of Lower Carboniferous age, found near the western margin of the Yarrol Basin. It represents a contribution to the larger project of biostratigraphic research on the Yarrol Basin, initiated by Hill in 1934 and continued since by members of the University of Queensland.

I am indebted to Professor D. Hill for valuable discussion and for her critical reading of the manuscript. Helpful advice from Dr. K. S. W. Campbell is also acknowledged. Photographs were taken by Mr. Chadwick and the map was drawn by Mr. A. Smith, both of the University of Queensland. The work was financed by a Research Grant held within the University of Queensland.

Stratigraphy. The Yarrol Basin (Hill 1951) consists of a narrow belt of Upper Palaeozoic strata, extending from Mackay, south-south-eastward to Mundubbera, a distance of more than 400 miles. Maximum width of the basin is 50 miles. Marine sedimentation began in the Middle Devonian (Givetian) and terminated early in Permian (Sakmarian), and except for interruptions in the marginal regions, a complete Upper Palaeozoic marine sequence has been preserved over a large part of the basin.

In the central western area of the basin, on Old Cannindah Station, the Tellebang and Baywulla formations, of Tournaisian and Viséan age respectively, reach a thickness of 5,000 feet. The Tellebang formation consists of shale and subgreywacke in its lower part, with thin bands of oolitic and non-oolitic limestone interbedded with calcareous subgraywacke, in the higher part. Fossils are abundant in the calcareous subgreywacke and become more numerous towards the top of the formation. The main gastropod assemblage, which is associated with a rich brachiopod fauna, occurs in a coarse calcareous breccia. The smaller gastropod fauna is preserved in a dark, fine-grained limestone approximately 750 feet below the breccia.

The Baywulla Formation consists almost entirely of limestone. It begins with 1,000 feet of coarsely oolitic limestone containing sparse brachiopods, solitary corals, and crinoidal debris, followed by non-oolitic, reef limestone which reaches a maximum thickness of 600 feet and contains abundant compound corals, of Viséan (D_1–D_2) age. Non-oolitic, crinoidal limestone, rich in solitary corals, cover the reef core for approxi-

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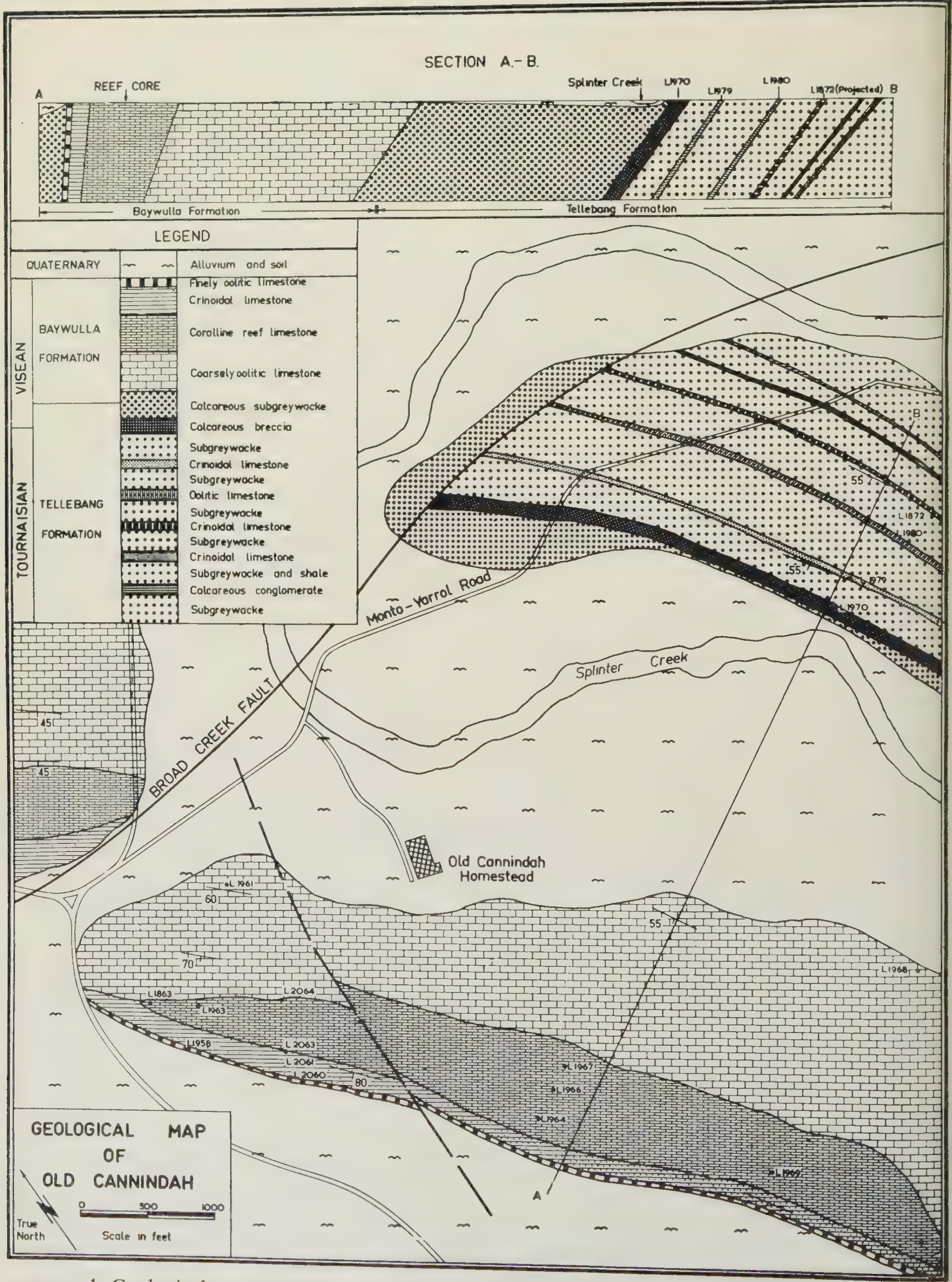

TEXT-FIG. 1. Geological map of Old Cannindah, showing localities from which faunas have been collected.

mately 300 feet, and the top of the formation is defined by a thin band (10 feet) of finely oolitic limestone rich in *Palaeacis* and with less numerous *Daviesiella*.

Faunas and localities. The higher fauna described in this paper occurs at L.1970 immediately west of Splinter Creek. It contains *Euphemites minutus* sp. nov., *Straparolus australis* sp. nov., *Phymatifer* sp., *Austroworthenia levis* sp. nov., and *Loxonema lamellosa*. In addition to the gastropods, a rich brachiopod assemblage is present, and this is being described in a separate work. The lower fauna, found at L.1872 about 1,100 feet west from L.1970, includes *Waagenella microstriata* sp. nov. and *Straparolus subdionysii* sp. nov., as well as brachiopods. Other numbers on the map indicate localities from which faunas have been collected. These faunas, now housed in the University of Queensland, are in the process of description, and are dominantly coralline and brachiopodan.

SYSTEMATIC DESCRIPTIONS

Class GASTROPODA Cuvier

Subclass STREPTONEURA Spengel

Order ASPIDOBRANCHIA Schweigger

Superfamily BELLEROPHONTACEA Ulrich & Scofield 1897.

Diagnosis. Symmetrical, planispiral, shell evolute, involute, or convolute; umbilicus open or absent; slit and selenizone present; ornament radial and transverse.

Family BELLEROPHONTIDAE M'Coy 1851

Diagnosis. Symmetrical, moderately thick shell, with wide, oval or elongate aperture; deep median slit on outer lip of aperture, and slit band or keel dividing rest of shell into two equal parts.

Genus EUPHEMITES Warthin 1930

Type species by selection of Waagen (1880, p. 131) *Bellerophon urei* Fleming 1828, p. 338; from Brankumhall Quarry, 1 mile north-east of East Kilbride, Lawrieston, Scotland; Lower Limestone, Hosie Group; Lower Carboniferous.

Diagnosis. Shell thick, globose, with rounded dorsum; dorsal lip bilobed; narrow slit and selenizone; parietal inductura extensive; 20–26 revolving costae well developed; early stage without umbilicus, later stages umbilicate.

Remarks. Knight (1941, pp. 122–3) and Weir (1931, pp. 841–55) have described the type species, *Bellerophon urei* Fleming, in detail, and Weir has identified and described other specimens from the type locality. Although the holotype of *B. urei* has been lost, Weir's interpretation of the species seems to be based on reliable evidence, and is followed in the present work.

In Europe the genus is represented by two species in the lower part of the Tournaisian (Z_2 zone), becomes abundant in the Viséan, and ranges into the Namurian. The type species occurs in the Scottish sequence in Coral Zones 2 and 3 and goniatite zones P_1, P_2, and E_1. The Namurian–Viséan boundary is fixed at the P_2–E_1 junction. Weir (1931, pp. 841–55) and Demanet (1941, pp. 263–4) have described the European species.

Several species have been described from the Mississippian and Pennsylvanian of North America, in beds of post-Tournaisian age.

Euphemites minutus sp. nov.

Plate 7, figs. 1–4

Holotype. F. 28610 Univ. Qld. Collection; from L. 1970 between Splinter Creek and Mt. Cannindah Portion 91, Parish Cannindah, County Yarrol, Queensland; Late Tournaisian–early Viséan.

Description. This is a small, globular, thin-shelled form, with minute umbilicus. The umbilical depression is narrow and deep. The anterior portion of the shell has not been preserved, and so the characters of the aperture are not known. In cross section, the whorl is transverse oval, slightly flattened, and extended laterally, towards the umbilicus. The ornament consists of well-marked linear ribs separated by wider, flat based grooves, and finer concentric growth-lines. Ribs vary from twelve in the early stages, to sixteen in later stages. The selenizone is narrow and inconspicuous, and is bordered by two ribs slightly higher than the others.

Remarks. E. minutus is characterized by its small size and comparatively coarse ornament. It differs from *E. urei* in the possession of fewer ribs and a less conspicuous selenizone. Its closest affinities are with *E. urei* var. *hindi* from Scotland, but this differs in having a closed umbilicus. The American species *E. lenticoformis* Weller from the Mississippian and *E. nodocarinatus* Hall from the Pennsylvanian differ markedly in shape and ornament. *E. vittatus* McChesney from the Pennsylvanian is similar in shape but has tuberculate ornament on the umbilical slopes.

E. minutus occurs in a calcareous grit, below the Viséan (D_1–D_2) reef limestones of Old Cannindah. Its associated brachiopod-gastropod fauna is suggestive of a late Tournaisian–early Viséan age.

Genus WAAGENELLA de Koninck 1883

Type species by selection of de Koninck (1883, p. 123)): *Bellerophon dumonti* d'Orbigny 1838, pl. 2, figs. 16–20 from Visé, Belgium; Viséan, Lower Carboniferous.

Diagnosis. Subglobose, involute shell, with regularly arched dorsum and large semilunate callosities curving back from the aperture margins over the umbilical region; umbilicus

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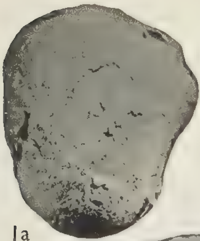
EXPLANATION OF PLATE 7

Figs. 1–4. *Euphemites minutus* sp. nov., Tellebang Formation, L. 1970, Por. 91, Parish Cannindah. 1*a*, Periphery and outer whorl, holotype (F. 28610), ×2. 1*b*, Apical view of same specimen. 2*a*, Apical view (F. 28612), ×2. 2*b*, Apertural view (F. 28613), ×2. 2*c*, Peripheral view, ×2. 3, Apical view (F. 28613), ×2. 4, Apertural view with part of whorl removed to show revolving striae on earlier whorl (F. 28611), ×6. 5, Apical view (F. 28612), ×3·5.

Figs. 6–8. *Waagenella microstriata* sp. nov., Tellebang Formation, L. 1872, Por. 91, Parish Cannindah. 6*a*, Inner whorl profile and aperture, holotype (F. 28666), ×2. 6*b*, Periphery and outer whorl, ×2. 6*c*, Apical view, ×2. 7, Apical view (F. 28665*a*), ×2. 8, Part of external mould (F. 28665*b*) showing selenizone and fine transverse striations, ×3·5.

Fig. 9. *Phymatifer sp.* Tellebang Formation, L. 1970, Por. 91, Parish Cannindah. 9*a*, Part of upper surface of whorl showing strong nodes (F. 28649). 9*b*, Same specimen, oblique view (nat. size).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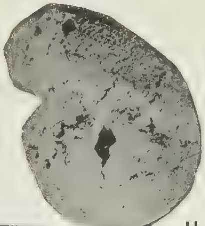
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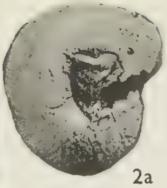
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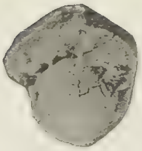
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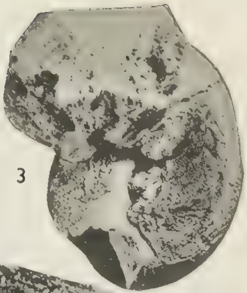
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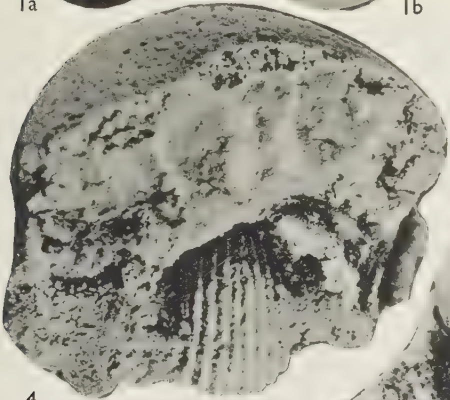
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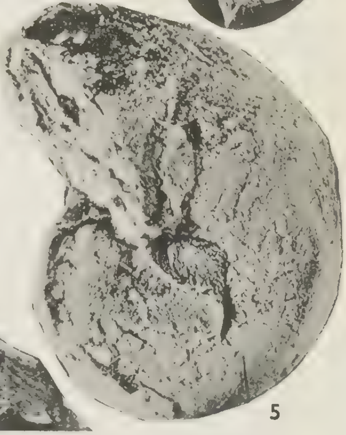
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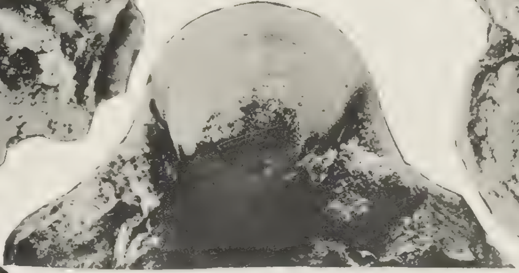
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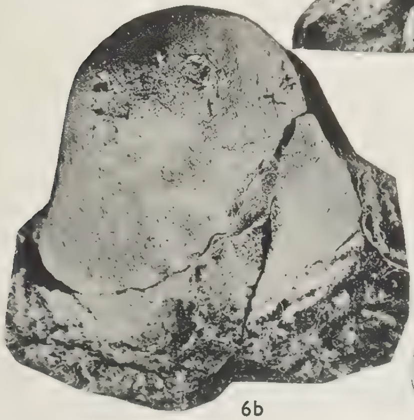
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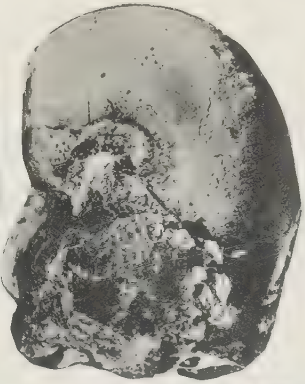
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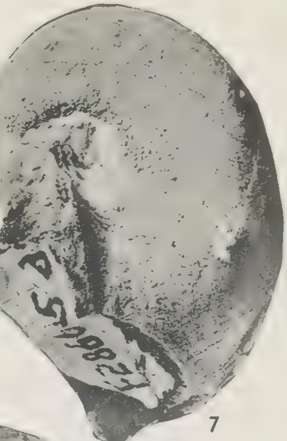

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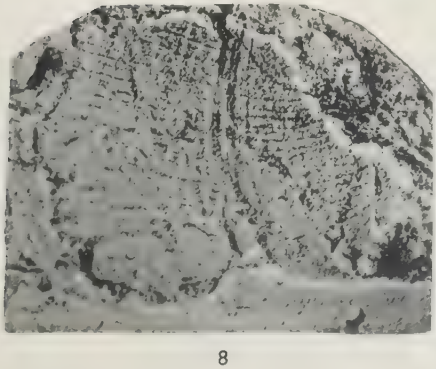
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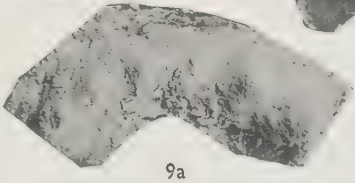
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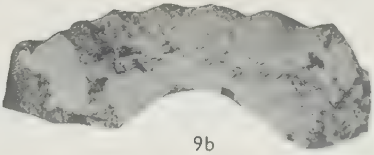
9b

closed; outer lip with broad shallow sinus, with central slit; narrow slightly raised selenizone, bordered by strong lirae; growth-lines fine, sharp; revolving costae fine.

Remarks. de Koninck (1882, p. 81) proposed the name *Waagenia* for species with reflected semilunate callosities at the margin of the aperture, and in 1883 (p. 123) indicated *Bellerophon dumonti* d'Orbigny as the type species. However, in a footnote to the explanation of his plate 38 (1883) he stated that the name *Waagenia* was preoccupied for an ammonoid genus and so he introduced the new name *Waagenella* for his bellerophontid genus.

Weir (1931, p. 813) quoted *Bellerophon ferussaci* d'Orbigny 1840 as the type species, apparently unaware of de Koninck's previous designation. Knight (1941, pp. 383–4) redescribed and figured the holotype of *B. dumonti* d'Orbigny from Visé, Belgium, and the present interpretation of the genus is based largely on Knight's description.

In his comprehensive study of the British and Belgian Carboniferous Bellerophontidae, Weir (1931, pp. 753–861) recognized six genera, viz.: *Bellerophon* de Montfort, *Waagenella* de Koninck, *Bucaniopsis* Ulrich, *Patellostium* Waagen, *Tropidocyclus* de Koninck, (= *Tropidodiscus* Meek & Worthen), *Zonidiscus* Spitz, and *Euphemus* M'Coy (= *Euphemites* Warthin), as well as minor groups within these. Generic distinction was based mainly on the nature of the aperture and inductura, the nature of the selenizone, and surface ornament. Shell shape (whorl cross-section) described by Weir appears to be quite variable within each genus, although Weir separated groups of species mainly on this character.

Examination of the holotype figured by Knight (1941) has shown that in many cases, the characters of generic importance—aperture, selenizone, surface ornament—are not preserved, and consequently interpretation of the type species and their respective genera is both difficult and not wholly reliable.

In the case of *Waagenella*, the author has supplemented Knight's description of the type species with material figured by de Koninck from the same locality. De Koninck's figures illustrate the finer surface ornament, which is not apparent on d'Orbigny's original specimen, and which is regarded by the present author as having generic significance.

Except for *W. portlocki* de Koninck, a small form found in the Upper Tournaisian, *Waagenella* in Belgium and Britain is restricted to beds of Viséan ($S–D_2$ zones) age. In North America *Bellerophon crassus* Meek and Worthen from the Pennsylvanian is the species with closest affinities to *Waagenella*.

Waagenella microstriata sp. nov.

Plate 7, figs. 6–8

Holotype. F. 28666 Univ. Qld. Collection; from L. 1872 between Splinter Creek and Mt. Cannindah, Portion 91, Parish Cannindah, County Yarrol, Queensland; Tournaisian.

Description. The shell is of medium size and globular shape, with the whorl widening rapidly towards the aperture. The aperture is transversely elliptical, and its lateral margins are extended and curved backwards over the umbilical region. The inner lip is somewhat thickened. A slightly raised selenizone extends posteriorly from the centre of the outer lip. Fine concentric growth-lines curve across the surface from the umbilical regions, meeting the selenizone more or less at right angles. Intersecting the growth-lines are small regular striae, parallel with the selenizone, and averaging thirty per 10 mm. on the dorsum.

Remarks. W. microstriata is characterized by its expanding whorl diameter and its finely striate surface ornament. Its closest affinities are with *W. dumonti* figured by de Koninck (1883, pl. 35, figs. 11–14) from the Carboniferous limestone of Visé. De Koninck's specimen is somewhat more globose than *W. microstriata*, but both have similar surface ornament. *Bellerophon stanvellensis* Etheridge (1892), from the Lower Carboniferous beds of the Stanwell district, probably belongs to the genus *Waagenella*. It is readily distinguished from *W. microstriata* by its much greater size, coarser growth-lines, absence of revolving striae, relatively smaller selenizone, and less rapidly expanding whorl width. Etheridge's type specimen has the recurved, much thickened apertural margins of *Waagenella*. Another, undescribed species of *Waagenella* has been found in the Lower Carboniferous beds of Delgalgil Creek, north of Monto in the Glassford district. This species is similar to *Bellerophon stanvellensis*, but is much smaller in size, has growth-lines curving backward from the selenizone, which is higher than that of *B. stanvellensis*. The exact locality and age of Etheridge's specimens from Stanwell and the age of the Delgalgil Creek species are not known. *W. microstriata* has been found only at the one locality so far. It occurs in a limestone, below the main reef development at Old Cannindah. Its associated fauna as well as its affinities with European species suggest a Tournaisian age.

Family EUOMPHALIDAE de Koninck 1881

Diagnosis. Low spired, discoidal to subtrochoidal, dextrally coiled shell; wide umbilicus; whorls rounded or angular; sinus in the upper part of the outer lip; ornament of concentric growth-lines, and in some genera, revolving striae.

Remarks. The euomphalids range from the early Palaeozoic to Cretaceous, reaching their maxima in the Devonian–Carboniferous and in the Triassic. The Carboniferous genera are characterized by the disappearance of the sinus and the tendency towards angularity in whorl cross-section. Further development of this tendency results in the appearance of nodes on the shoulders of the whorls.

Knight (1934, pp. 142–5) recognized only one Carboniferous genus, *Straparolus* Montfort 1810, and one subgenus *Euomphalus* Sowerby 1812 in the Euomphalidae, and he referred the genera *Schizostoma* Bronn 1834, *Phymatifer* de Koninck 1881, and *Phanerotinus* Sowerby 1844 to the synonymy of *Straparolus*. The main variation within the family Euomphalidae appears to be in shell form and whorl contour. *Straparolus* has the most trochiform shell, with evenly arched whorls, *Euomphalus* has a low, coiled shell, with angulation of the whorl and a tendency towards nodal development. If such differences are of generic value then *Phymatifer* de Koninck 1881 can be separated on the basis of nodal development on the upper shoulders of its whorls, and on its discoidal, depressed shell. *Phanerotinus* Sowerby can be distinguished by its open coiling and leaf-like expansions of the outer whorl. The shell of *Schizostoma* Bronn is similar to that of *Euomphalus* but the whorls are more angular. In view of their differences, it would seem advisable to accept the generic status of these forms.

Genus STRAPAROLUS de Montfort 1810

Type species by original designation *Straparolus dionysii* Montfort 1810, p. 174, from Namur, Belgium; Lower Carboniferous.

Diagnosis. Subdiscoidal to subtrochiform shell, with nucleus flatly coiled; rounded whorls, wide umbilicus; low, revolving ridge on upper whorl surface, and sutures at line of contact of whorls, parietal lip with thin inductura, outer lip bent slightly backward to form weak sinus; ornament of fine growth-lines and fine revolving lirae.

Remarks. The genus has been treated exhaustively by Knight (1934; 1941; 1947), who has given its range as Devonian to Lower Pennsylvanian.

Straparolus australis sp. nov.

Plate 8, figs. 1–4

Holotype. F. 28615, Univ. Qld. Collections; from L.1970 between Splinter Creek and Mt. Cannindah, Portion 91, Parish Cannindah, County Yarrol, Queensland. Late Tournaisian–early Viséan.

Description. The shell is subtrochiform in shape with the first two whorls almost planispiral, and subsequent whorls becoming weakly trochiform. Sutures are relatively deep. Slight angularity of the upper shoulder develops in the later whorls, and this is separated from the upper suture by a somewhat flattened band. The tendency towards angularity is less apparent in the lower shoulder of the later whorls. The umbilicus is wide and steep sided. Ornament consists of numerous fine concentric growth-lines which curve slightly over the upper shoulder; no revolving striae can be distinguished.

Dimensions.

	Holotype	*Syntypes*	
Number of whorls	4	3+	5
Height of whorl	10 mm.	7	9
Width of whorl	13 mm.	=10	10
Height of shell	17 mm.		
Width of shell	33 mm.		

Remarks. *Straparolus australis* resembles the species identified as *S. dionysii* from the Carboniferous of England and Ireland, but is generally larger and slightly less trochiform. Of the Belgian species, its closest affinities are with *S. explanatus* de Koninck 1881 (p. 125, pl. 21, figs. 5–7) from the Viséan limestones of Visé. Like the type species, its whorls are well arched and not noticeably angular. It differs in this respect from the American species *S. savagei* Knight which has three distinct angular ridges.

An undescribed species of this genus occurs in beds of Tournaisian age in the Rockhampton district, Queensland. This form differs from *S. australis*, in that a row of rounded nodes occurs on the upper shoulder of the whorls, and its shape is less trochiform.

S. subdionysii sp. nov. is the second species which occurs in the limestones between Splinter Creek and Mt. Cannindah. It first appears about 500 feet below the bed with *S. australis*, and is also found associated with *S. australis*. *S. subdionysii* is a smaller, higher shell with distinct revolving bands.

Straparolus subdionysii sp. nov.

Plate 8, figs. 5*a–c*

Holotype. F. 28637, Univ. Qld. Collection; from L. 1872, between Splinter Creek and Mt. Cannindah, Portion 91, Parish Cannindah, County Yarrol, Queensland; Tournaisian.

Description. The shell is symmetrically coiled, subtrochiform in shape, with a steep-sided umbilicus of moderate width. The whorls are fairly well arched in profile, and separated from earlier whorls by small sutures. A low ridge or shoulder is developed on the upper surface of the whorl, while the lower surface is well rounded. A band consisting of three minute ridges extends along the outer face of the whorl, and is bordered by slight depressions. The ornament consists of fine growth-lines.

Dimensions.

	Holotype	*Syntype A*
Number of whorls	4	4
Height of whorls	10 mm.	6·5 mm.
Width of whorls	10 mm.	8 mm.
Height of shell	15 mm.	9 mm.
Width of shell	23 mm.	17 mm.

Remarks. S. subdionysii has marked affinity with the type species *S. dionysii*, and is distinguished from *S. australis* by its more trochiform shape. It resembles *S. savagei* Knight in the development of the raised band, but differs from the American species in shape. It occurs in beds of Tournaisian age.

Genus PHYMATIFER de Koninck 1881

Type species by selection of Knight 1941, p. 243: *Euomphalus pugilis* Phillips 1836, p. 225; from Bolland, Yorkshire, England; Lower Carboniferous.

Diagnosis. Discoidal, evolute shell; depressed spire, wide umbilicus; whorls angular, with noses on upper and lower surfaces; suture sharp, deep; ornament of faint growth-lines, slightly curved over nodes.

Remarks. De Koninck (1881, p. 149) erected the genus for species with tubercles developed on the upper and lower surfaces of the whorl. Knight believed that this tendency was apparent in species of *Euomphalus* s.s. and that it was not of generic significance. Consequently he suggested that *Phymatifer* was a synonym of *Euomphalus*. The tuberculate species and the non-tuberculate ones may form a gradational series, but

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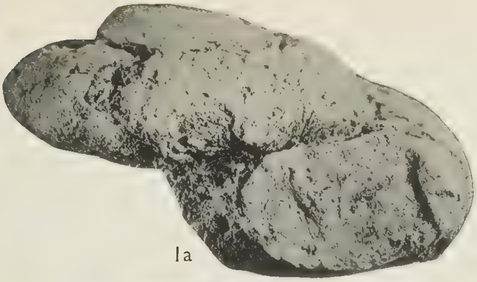
EXPLANATION OF PLATE 8

Figs. 1–4. *Straparolus australis* sp. nov., Tellebang Formation, L. 1970, Por. 91, Parish of Cannindah. 1*a*, Apertural row and shell profile, holotype (F. 28615), ×2. 1*b*, Apical view, ×2. 2, Apical view (F. 28618), ×2. 3, Apertural view and shell profile (F. 28617), ×2. 4, Part of whorl showing fine transverse striation, ×2.

Figs. 5*a–c*. *Straparolus subdonysii* sp. nov., Tellebang Formation, L. 1872, Por. 91, Parish Cannindah. 5*a*, Apertural view and shell profile, holotype (F. 28637), ×2. 5*b*, Apical view, ×2·25. 5*c*, Shell profile, ×2·5.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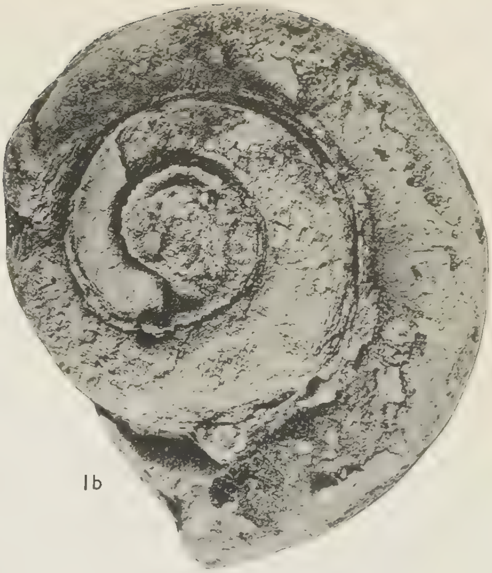
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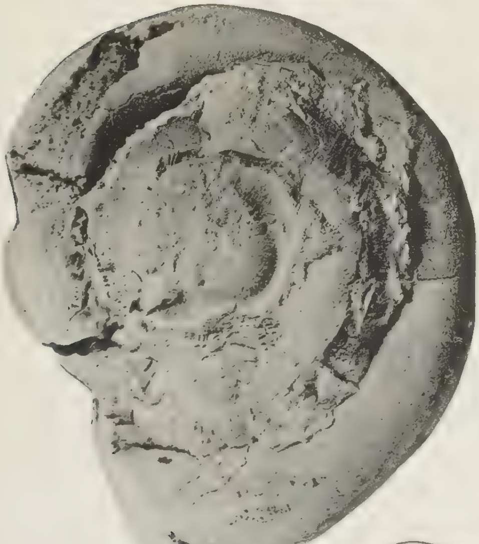
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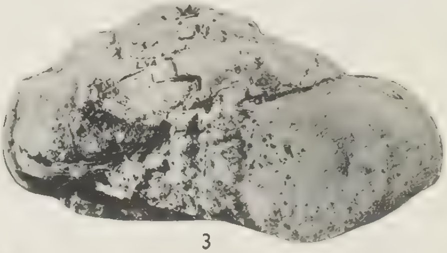
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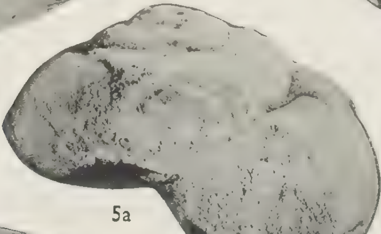
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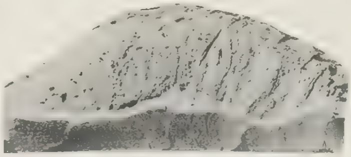
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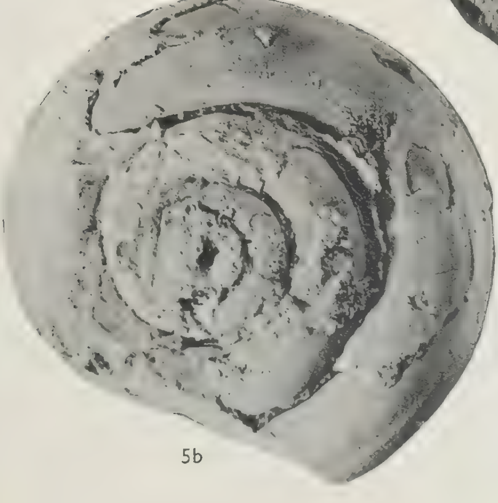
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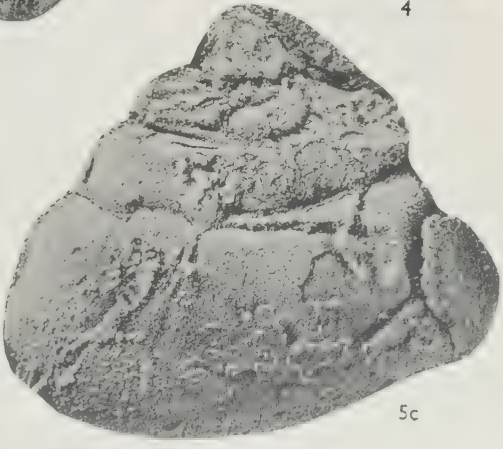

5c

MAXWELL, Lower Carboniferous Gastropods

this has not yet been demonstrated. On the other hand, the discoidal, tuberculate forms are fairly readily distinguished from the others, and their grouping into a separate genus may have practical taxonomic and stratigraphic value. Because of this, the present author regards *Phymatifer* de Koninck as an acceptable, valid genus.

Phymatifer occurs in the limestones of Bolland, England, and Visé, Belgium, which are Viséan in age. No American species appear to belong to the genus.

In Queensland one species occurs in the limestones at Old Cannindah, and a smaller related species occurs in beds of Tournaisian age at Rockhampton.

Phymatifer sp.

Plate 7, fig. 9

Locality. L. 1970 between Splinter Creek and Mt. Cannindah, Portion 91, Parish Cannindah, County Yarrol, Queensland; late Tournaisian–early Viséan.

Remarks. Parts of the whorl showing trapezoidal cross-section, and the upper shoulder with well-developed nodes which continue towards the inner margins as low ridges have been found. Spacing of nodes is about 7 mm. The shape of the whorl cross-section and the nature of the nodes are strikingly similar to those of *Phymatifer pugilis*, the type species, from Bolland, Yorkshire. *Phymatifer tuberosus* de Koninck (1881, pl. 13, figs. 4–7) from the Tournaisian limestones of Tournai, Belgium, has similar nodal development, but differs in that the shell is subtrochiform in shape.

Family PLEUROTOMARIIDAE d'Orbigny

Diagnosis. Conical dextrally coiled, shell; wide spiral angle; angular to subangular whorls flattened base; well-defined selenizone; ornament of transverse and revolving lines, variable in development.

Remarks. The family ranges from the Silurian through to the Jurassic, the greatest number occurring in the Silurian, Devonian, and Carboniferous.

Genus AUSTROWORTHENIA gen. nov.

Type species Austroworthenia levis sp. nov.

Diagnosis. Small, anomphalous, trochiform shell; selenizone slightly concave, broad, bordered by two carinae; whorl profile with two angulations, upper one coinciding with top carina of selenizone, and projecting as ridge; lower angulation less prominent; surface weakly ornamented with fine transverse growth-lines; no revolving or nodular ornament.

Remarks. *Austroworthenia* has been erected for those species which are similar in shape to *Worthenia* de Koninck, *Baylea* de Koninck, and *Hypselentonia* Weller, but lack the strong revolving ornament of these genera. In Australia only one species, the genero-type, has so far been recognized, and this occurs in beds of late Tournaisian–early Viséan age. *Worthenia munsteriana* de Koninck (1883, p. 66, pl. 32 *bis*, figs. 6, 7) from the Tournaisian of Tournai, Belgium, is the only European species which could be referred to the new genus. The other species figured by de Koninck all have marked revolving ornament.

Austroworthenia levis sp. nov.

Plate 9, figs. 1–5

Holotype. F. 28645, Univ. Qld. Collection; from L. 1970, between Splinter Creek and Mt. Cannindah, Portion 91, Parish Cannindah, County Yarrol, Queensland. Late Tournaisian–early Viséan.

Description. The shell is comparatively small (9–19 mm. high), anomphalous and trochiform. The upper whorl surface is flattened, and slopes at an angle of 125° from the axis to the upper angulation which is strongly carinate. The upper angulation coincides with the carina bordering a wide, slightly concave selenizone. A smaller, less clearly defined carina occurs along the lower edge of the selenizone. The lower angulation is less prominent and slightly rounded.

Ornament consists of extremely fine growth-lines, directed backward at approximately 30° on the upper surface, but curving forward across the selenizone, and then backward across the lower whorl surface. The growth-lines are very difficult to identify. No revolving costae or carinate nodes have been found.

Dimensions.

	Holotype (F. 28645)	*F. 28646*	*F. 28647*	*F. 28648*	*F. 28643*
Height (mm.)	19	15	12	11	7·5
Width of base (mm.)	16	14	10	11	6
Pleural angle	55°	60°	56°	56°	53°

Remarks. Dimensions and proportions of *A. levis* are similar to those of the majority of species of *Worthenia* described from Belgium. In general, species of *Baylea* from that country are much larger.

Order CTENOBRANCHIA Schweigger

Family LOXONEMATIDAE Termier and Termier

Diagnosis. Turbinate, long shells, without selenizone; ornament of regular growth-lines, sometimes sinuous; revolving striae sometimes developed.

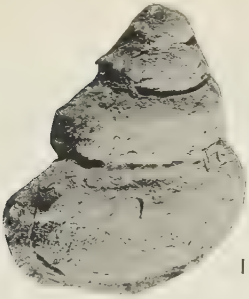
Genus LOXONEMA Phillips 1841

Type species by selection of King 1850, p. 209: *Terebra sinuosa* J. de C. Sowerby 1839, p. 619; from Garden House, Aymestry, Shropshire, England; Silurian.

EXPLANATION OF PLATE 9

Figs. 1–5. *Austroworthenia levis* sp. nov., Tellebang Formation, L. 1970, Por. 91, Parish Cannindah. 1*a*, Shell profile, holotype (F. 28645*a*), ×2. 1*b*, Latex impression of external mould of holotype (F. 28645*b*), ×2. 2, Shell profile (F. 28646), ×2. 3, Shell profile (F. 28643), ×2. 4, Shell profile (F. 28647), ×2. 5, Shell profile (F. 28648), ×2.

Figs. 6–11. *Loxonema lamellosa* sp. nov., Tellebang Formation, L. 1970, Por. 91, Parish Cannindah. 6, Cross-section of higher whorls and entire lower whorl (F. 28642), ×2. 7, Shell profile, showing aperture; specimen decorticated (F. 28641), ×2. 8, Latex impression of external mould showing transverse costation (F. 28644), ×2. 9, Shell profile and inner lip; specimen decorticated, holotype (F. 28639), ×2. 10, Same view (F. 28643), ×2. 11, Shell profile (F. 28644), ×2.



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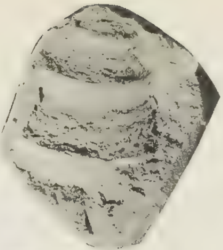

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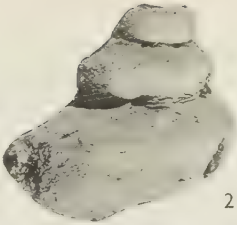

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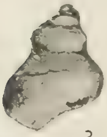

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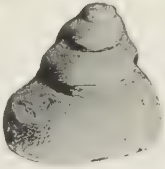

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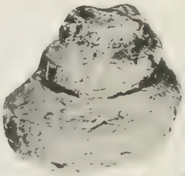

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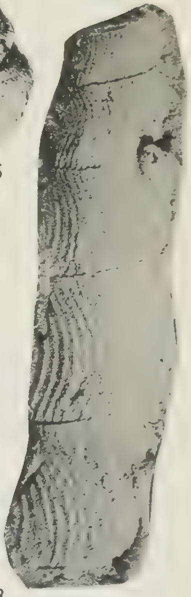

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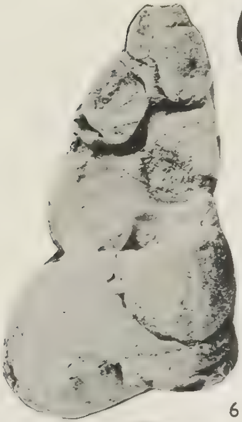

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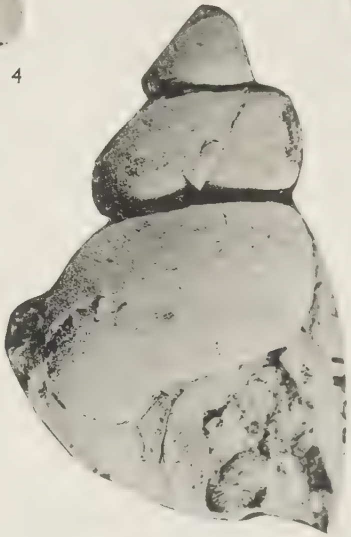

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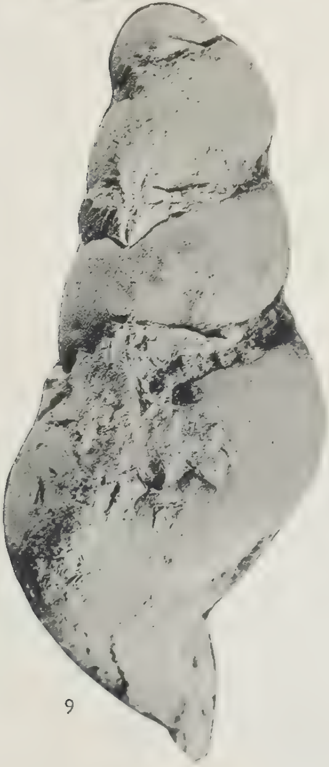

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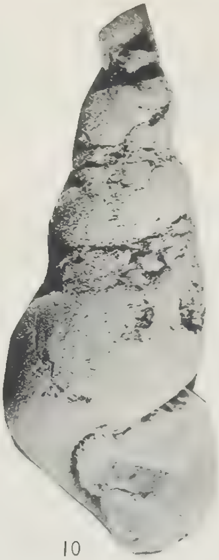

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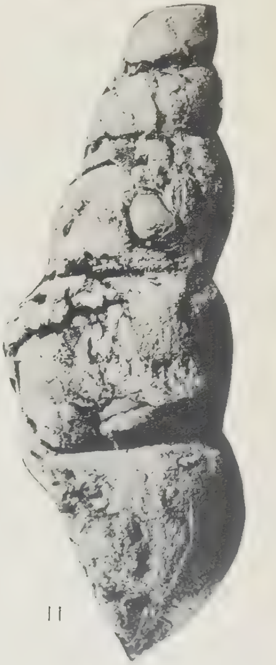

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MAXWELL, Lower Carboniferous Gastropods

Diagnosis. Small, high-spired, medium-sized shell; no umbilicus; whorl profile evenly convex; sutures deep; no selenizone, notch, or slit; outer lip with deep sinus; ornament of fine growth-lines curving backward from upper suture to lower shoulder then forward.

Remarks. Loxonema was erected by Phillips 1841 for high-spired shells with fine oblique ornament. As defined by Phillips and later authors, the genus embraces a widely ranging group from the Ordovician to the Carboniferous. Finer subdivision, based possibly on external ornament, might seem desirable, but the narrow limits of variation make this difficult. The species from the Belgian Carboniferous appear to be separable into two main groups, namely, those with fine, regular growth-lines and those with concentric ribs or nodal ridges extending across the whorl from upper to lower suture. De Koninck (1881, p. 40) recognized this difference and separated his species into '*Laevigata*' and '*Costata*'. It is doubtful, however, whether this division has any stratigraphic value since both costate and laevigate forms range through from the Devonian into the Carboniferous.

Loxonema lamellosa sp. nov.

Plate 9, figs. 6–11

Holotype. F. 28639, Univ. Qld. Collection; from L. 1970, between Splinter Creek and Mt. Cannindah, Portion 91, Parish Cannindah, County Yarrol, Queensland; late Tournaisian–early Viséan.

Diagnosis. Medium-sized, turbinate shell, with five to seven whorls; whorls convex with slight shoulders adjacent to upper and lower sutures, no umbilicus, no selenizone; ornament of regular growth lamellae.

Description. The shell is turbinate, ranging in height from 19 to 45 mm. and in basal width from 10 to 18 mm. Its apical angle averages 25°. Five to seven whorls are developed. The whorl profile is moderately arched, with low shoulders developed between the periphery and the upper and lower sutures. The sutures are deep. No umbilicus is formed. The ornament consists of comparatively regular, arcuate growth lamellae which curve backwards from the upper suture to the periphery and then forwards to the lower suture.

Remarks. L. lamellosa differs from the type species in the curvature of the growth lamellae. In *L. sinuosum*, the growth-lines extend forward from the upper aperture at approximately 45°, and continue across the lower shoulder, without interruption. In *L. lamellosa*, the growth-lines are concave towards the aperture, being almost perpendicular to the sutures, and arching backwards over the periphery. Of the species in the Belgian Carboniferous faunas, it is most similar to the one from the Viséan limestone of Visé, figured by de Koninck (1881, pl. 6, fig. 18) as *L. pulcherrimum* M'Coy. No American species is comparable with *L. lamellosa*.

Etheridge (1892, p. 285, pl. 15, fig. 17) figured a species from the Rockhampton district, which he compared with *L. rugifera* Phillips. This form is readily distinguished from *L. lamellosa* by its coarse ornament, shell shape, and whorl profile. *L. lamellosa* occurs in the Mundubbera district, in beds of Late Tournaisian–early Viséan age.

REFERENCES

BRONN, H. G. 1834. *Lethaea Geognostica*, **1**, Stuttgart [not seen].

DEMANET, F. 1941. Faune et stratigraphie de l'Étage Namurien de la Belgique. *Mém. Mus. Hist. Nat. Belg.* **97**, 1–327, pl. 1–18.

ETHERIDGE, R. jun. 1892. The Geology and Palaeontology of Queensland and New Guinea. *Publ. geol. Surv. Qd.* **92**, 1–756, pl. 1–68.

FLEMING, J. 1828. *A history of British animals.* London [not seen].

HILL, D. 1951. Geology of Queensland. *Handbook A.N.Z.A.A.S., Brisbane*, 13–24.

KING, W. 1850. A Monograph of the Permian fossils of England. *Palaeontogr. Soc.*

KNIGHT, J. B. 1934. The gastropods of the St. Louis, Missouri, Pennsylvanian outlier, VI, the Euomphalidae and Platyceratidae. *J. Paleont.* **8**, 139–66, pl. 20–26.

—— 1941. Paleozoic Gastropod Genotypes. *Spec. Pap. geol. Soc. Amer.* **32**, 1–510, pl. 1–96.

KONINCK, L. G. DE. 1881. Faune du calcaire carbonifère de la Belgique, 3^{e} partie, Gastéropodes. *Ann. Mus. Hist. nat. Belg., Sér. Paléont.* **6.**

—— 1882. Notice sur la famille des Bellerophontidae suivie de la description d'un nouveau genre de cette famille. *Ann. Soc. géol. Belg.* **9**, 72–90.

—— 1883. Faune du Calcaire carbonifère de la Belgique, 4^{e} partie, Gastéropodes (suite et fin). *Ann. Mus. Hist. nat. Belg., Sér. Paléont.* **8.**

M'COY, F. 1844. *A synopsis of the characters of the Carboniferous Limestone fossils of Ireland.* Dublin.

—— 1851. On some new Silurian Mollusca. *Ann. Mag. nat. Hist.* (2), **7**, 45–63.

MONTFORT, P. D. DE. 1810. *Conchyliologie systématique, et classification méthodique des coquilles; offrant leurs figures, leur arrangement générique, leurs descriptions caractéristiques, leurs noms; ainsi que leur synonymie en plusieurs langues.* **2**, *Coquilles univalves, cloisonnées.* Paris [not seen].

ORBIGNY, A. D'. 1838. *Histoire naturelle générale et particulière des céphalopodes acétabulifères vivants et fossiles.* Paris [not seen].

PHILLIPS, J. 1841. *Figures and descriptions of the Palaeozoic fossils of Cornwall, Devon, and West Somerset.* London.

SHIMER, H. W. and SHROCK, R. R. 1944. *Index fossils of North America.* Massachusetts. Inst. Technology.

SOWERBY, J. 1812. No. III of the *Mineral Conchology of Great Britain*, **1**, London.

SOWERBY, J. DE C. 1839. *In* MURCHISON, R. I., *The Silurian System.* London.

—— 1844. *Mineral Conchology of Great Britain*, **7**, London.

TERMIER, G., and TERMIER, H. 1950. *Invertébrés de l'Ère Primaire.* Tome II, Fasc. III, Mollusques. Paris.

WAAGEN, W. H. 1880. Salt Range Fossils. Pt. 2. *Palaeont. Indica* (13), **1**, 73–183, pl. 7–16.

WARTHIN, A. S. 1930. Micropaleontology of the Wetumka, Wewoka, and Holdenville formations. *Bull. geol. Surv. Oklahoma*, **53.**

WEIR, J. 1931. The British and Belgian Carboniferous Bellerophontidae. *Trans. roy. Soc. Edin.* **56**, 767–865, pl. 1–9.

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CAMBRIAN TRILOBITES FROM THE AMANOS MOUNTAINS, TURKEY

by W. T. DEAN and R. KRUMMENACHER

Abstract. Certain Palaeozoic rocks of the Amanos Mountains in southern Turkey have been investigated, and their stratigraphical relationships are briefly reviewed. Trilobites of Middle Cambrian, or Acadian, age have been collected from strata previously assigned to the Devonian. The specimens described here include the genus *Pardailhania*, together with an indeterminate agnostid, and suggest affinities with North African and eastern North American faunas of similar age.

In the summer of 1957 one of the writers (R. K.) was sent by the Shell Petroleum Company of Turkey to study geological sections in the Amanos Mountains. A detailed examination was made of a series of rocks previously attributed to the Devonian (Dubertret 1953), though palaeontological proof was lacking. From these were collected trilobites, now known to be of Middle Cambrian age, which are described in this paper.

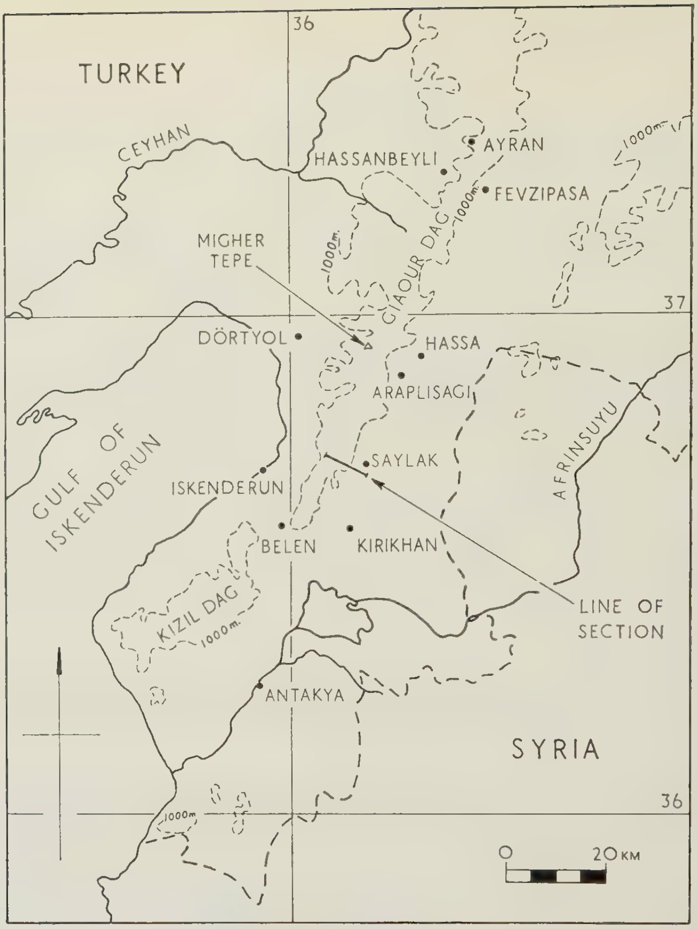
The writers are indebted to the management of the N. V. de Bataafsche Petroleum Maatschappij for permission to publish the following results, and to Professor W. F. Whittard who has kindly read and criticized the manuscript.

The Amanos is the southernmost massif in the succession of coastal ranges running north–south along the Mediterranean coast from Turkey towards Israel. About the latitude of Iskenderun the Belen Pass (680 metres) divides the Amanos into two well-defined blocks, the Kizil Dag in the south, and the Giaour Dag, or Nurdaglari, in the north (text-fig. 1). The latter, culminating in the Migher Tepe (2,224 metres), exhibits on its eastern flank various geological formations which have not been encountered elsewhere in the area. A geological map on the scale 1:200,000, drawn by Dubertret, was published in 1952 by the Institut Géographique National, Paris, whilst Blumenthal and Turkenal, two geologists of the Maden Teknik Ve Arama Enstitusu, Ankara, had earlier, in 1944, completed the Malatya sheet of the 1:800,000 geological map of Turkey. In the Amanos the latter map shows mainly undifferentiated Palaeozoic rocks, limited on their eastern side by a narrow strip of Permo-Carboniferous(?) limestones.

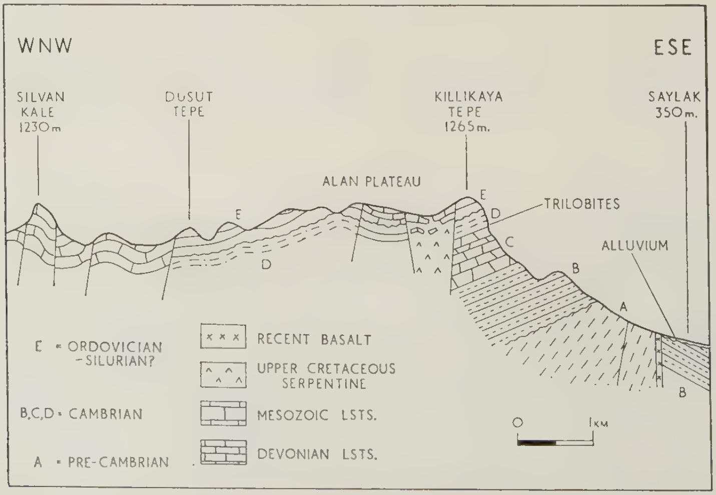
STRATIGRAPHY

Owing to the broken nature of the terrain of the Giaour Dag, continuous successions can be followed for only short distances. The best-exposed section that has been examined lies west-south-west of Saylak, 12 kilometres north by east of Kirikhan, and it was here that trilobites were found. Access to the section is still difficult, and the following succession was established mainly along a mule track connecting Araplisagi with the mountains, and completed along a forestry road which, in 1957, was being built south-east of Dörtyol. Owing to the absence of local stratigraphical names the formations in this description are given the letters A to E in ascending order (text-fig. 2).

[Palaeontology, Vol. 4, Part 1, 1961, pp. 71–81, pl. 10.]



TEXT-FIG. 1. Map of southern Turkey showing the Kizil Dag and Giaour Dag blocks of the Amnos Mountains.



TEXT-FIG. 2. Section across the Amnos Mountains near Saylak. Vertical scale doubled.

Formation A. A monotonous series of alternating, well-bedded, quartzitic sandstones and phyllitic shales, dark red to dark green-brown in colour. The rocks are unfossiliferous and more than 1,000 metres thick. At Araplisagi they dip to the east-south-east at 45 degrees, but become steeper towards the Migher Tepe. The beds are separated by a strong, angular unconformity from:

Formation B. Massive, pinkish, quartzitic sandstones and conglomerates with some thin intercalations of ferruginous, micaceous shale. Pebbles of pale quartzite, dark schist, and igneous material occur throughout, and cross-bedding is common. The rocks become more ferruginous and shaly towards the top, culminating in an horizon of ferruginous shales a few metres thick. No fossils have been found and the total thickness is about 600 metres. There is a gradual passage to:

Formation C. The lower beds include lenses of blue-grey limestone, or coarsely crystalline, dark, dolomitic limestone, in a ferruginous, shaly matrix. Higher in the succession coarsely crystalline, dark-blue to black, dolomitic limestones or dolomites form beds from 20 to 50 cm. thick, with thin, shaly intercalations. The rocks are 185 metres thick, apparently unfossiliferous, and followed conformably by:

Formation D. The basal beds comprise current-bedded, calcareous shales and shaly limestone, whilst higher in the succession are dark green, calcareous shales, both laminated and cross-bedded, with vugs at some points. The basal beds contain comminuted shell fragments and worm tracks. Middle Cambrian trilobites have been collected 5 metres above the base of the formation, along the road climbing from Saylak to the Alan Plateau (text-fig. 2). Total thickness is 250 metres and the rocks are separated by a disconformity from the overlying:

Formation E. Massive, pale, coarse to conglomeratic, quartzitic sandstones. Green, sandy, micaceous shales alternate with nodular, green-brown, quartzitic sandstones higher in the succession. The topmost strata comprise a few layers of soft, sandy shale, of a characteristic deep-purple colour. No fossils have been found and the thickness, as measured above Dörtyol, is 85 metres.

The outcrop of Formation E was traced northwards as far as the village of Ayran, 8 kilometres north-north-west of Fevzipasa, where it was found to be much better developed. The sediments there, 1,115 metres thick, exhibit structures attributed to slumping in the upper part of the section, where worm tracks and the so-called trilobite tracks known as '*Fraena*' were encountered. The only stratigraphically useful fossil yet found in this formation is a badly damaged trilobite; at one time this was supposed to belong to the Silurian genus *Acaste* (Frech 1916, p. 51), but the specimen has since been redetermined by R. Richter as *Dalmanitina sp.* and held to indicate an Ordovician age (Dubertret 1953).

Above Dörtyol, Formation E is transgressed, though without angular unconformity, by a massive, blue-grey, dolomitic breccia which passes upwards gradually into a well-bedded, pale, gypsiferous, dolomitic limestone with some thick intercalations of yellowish mudstone. The only fossils found were a few indeterminate algae and polyzoa, but a regional study of the formation suggests that it can be equated with the Devonian rocks of Hassanbeyli to the north (Blankenhorn 1891, p. 60).

The Middle Cambrian or, more precisely, Lower Acadian age of Formation D is shown by the contained trilobites, belonging to the genus *Pardailhania*. Formations B, C, and D form a conformable succession, the whole of which is believed to be Cambrian in age, and the lower beds may represent an undetermined portion of the Lower Cambrian. Formation A is thought to be Pre-Cambrian in age as it is strongly transgressed by the supposed Cambrian of Formation B. The Ordovician age of Formation E has been indicated in the Aryan area, and subsequently a general transgression at the base of the series of calcareous and dolomitic rocks of Devonian age occurred throughout the Amanos (text-fig. 3).

Generally speaking, the deposition of the Cambrian rocks throughout the Middle East commenced with a continental or littoral environment which produced mainly coarse clastics, together with occasional evaporites, viz. the 'Cambrian Salt' of Persia. In the Middle Cambrian these conditions were terminated by a marked marine transgression directed approximately southwards, carbonates being deposited as far south as Persia and the Gulf of Akaba, though they have not been reported from Saudi Arabia. At about the end of Cambrian times, sometimes following a marked disconformity, deposition of clastics recommenced and continued through the Ordovician and Silurian. The great accumulation of Lower Palaeozoic clastic rocks found in the north of the Amanos, with their general lack of fossils and abundance of worm-tracks, slumping features, and nodular shales, suggests rapid, flysch-like sedimentation under unstable tectonic conditions.

The facies of the Lower Palaeozoic rocks of the Amanos are comparable with those of the Anti-Atlas, probably forming part of the same geosynclinal area, and it is interesting that the Middle Cambrian trilobites described in this paper bear most resemblance to a Moroccan species which, in turn, exhibits affinities with an eastern North American form.

The Cambrian rocks of the Amanos apparently escaped the effects of the Caledonian Orogeny, and it is expected that they will be found to pass laterally into part of the highly metamorphosed series of the Taurus Mountains farther north. Prior to Devonian times some of the Ordovician and ?Silurian rocks were eroded in the south of the area, but during the remainder of the Palaeozoic deposition the Amanos acted as a stable 'platform' which received considerably reduced sedimentation.

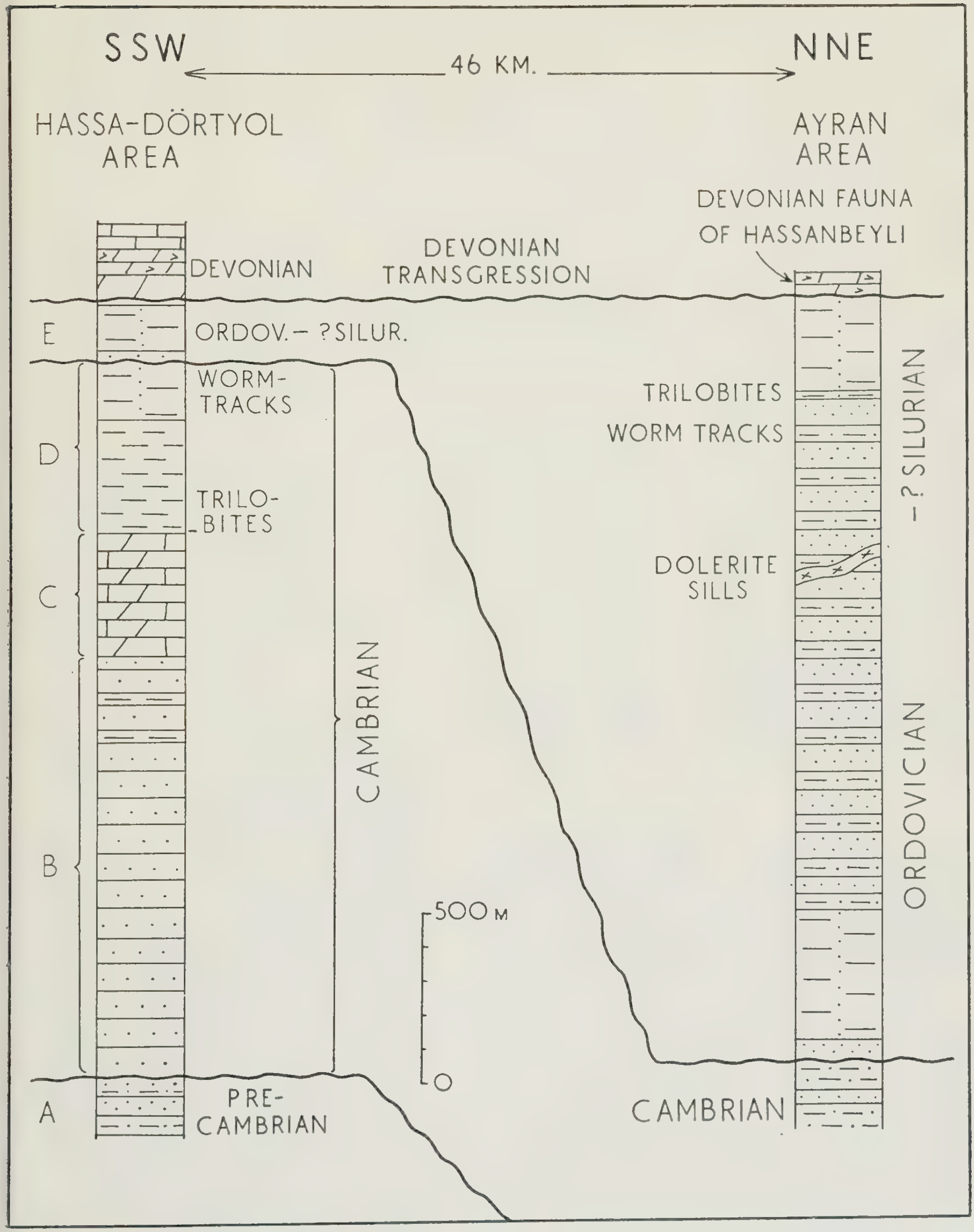
SYSTEMATIC PALAEONTOLOGY

All the fossils found in the Cambrian rocks of the Amanos are trilobites from only one locality. Ten specimens, preserved as internal and external moulds, were collected; nine belong to one species, described below as *Pardailhania* cf. *barthouxi*, and one to a generically indeterminate agnostid.

Family SOLENOPLEURIDAE Angelin 1854

Subfamily SOLENOPLEUROPSINAE Thoral 1948 (*nom. transl.* herein *ex* SOLENOPLEUROPSIDAE Thoral 1948) = SAOINAE Hupé 1953

The genera *Pardailhania* Thoral 1947, *Rimouskia* Resser 1938, *Sao* Barrande 1846, and *Solenopleuropsis* Thoral 1947, have been grouped together by Poulsen (1954, pp. 445–6; *in* Moore 1959, p. O 276) in the subfamily Saoinae, a name used originally as Family Saoidae Hupé 1953. If these genera are accepted as belonging to the same



TEXT-FIG. 3. Vertical sections in the northern Amnos Mountains.

subfamily, then the name Solenopleuropsinae, derived from the familial name proposed earlier by Thoral (1948, p. 82) for the genera *Solenopleuropsis* and *Pardailhania*, has priority.

Genus PARDAILHANIA Thoral 1947

Type species *Solenopleura? hispida* Thoral, 1935, by original designation

Pardailhania cf. *barthouxi* (Mansuy)

Plate 10, figs. 1, 2, 4, 7, 9, 10–13

1922 *Ptychoparia barthouxi* n. sp., Mansuy, p. 288, pl. 10, figs. 4*a–g*.

Description. Cephalon roughly semicircular in outline, with median length about half the breadth. Though the specimens are somewhat flattened, the glabella appears to be moderately convex, with basal breadth about one-third that of the cephalon and three-quarters or more of its own length. Glabellar outline almost a trapezium, its sides converging forwards gradually to the frontal lobe at about 20 to 25 degrees; the latter is delimited by a shallow preglabellar furrow, generally transversely straight or gently convex forwards. Almost all the specimens have a smooth, unfurrowed glabella, but one (Pl. 10, fig. 7) shows three pairs of faintly impressed glabellar furrows. First pair of furrows barely discernible; second furrows straight, extending only a short distance adaxially from axial furrows. Basal glabellar furrows run adaxially and then rearwards from the axial furrows without reaching occipital furrow, each extending across the glabella about one-quarter of its basal breadth. The three glabellar lobes so defined are of roughly equal length (*exsag.*), each about one-quarter the median length of the glabella. Axial furrows deep, almost straight or slightly convex abaxially; in only the largest specimen do they contain a pair of poorly developed anterior pits. In front of the preglabellar furrow is a broad (*sag.*), flat or slightly convex, preglabellar field, equal to about one-quarter of the glabellar length; in front of this the anterior border rises

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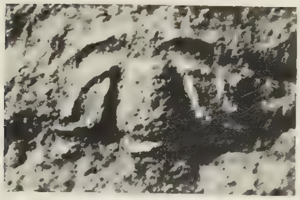
EXPLANATION OF PLATE 10

Figs. 1, 2, 4, 7, 9, 10–13. *Pardailhania* cf. *barthouxi* (Mansuy). Lower or lower Middle Acadian, road leading to the Alan Plateau above Saylak, north-north-east of Kirikhan, Turkey. 1, Km 565 d1, internal mould of immature cranidium. 2, 4, Km 565 d2, external mould and corresponding latex cast of cranidium showing smooth glabella and broad (*sag.*) preglabellar field. 7, Km 565 d3, latex cast from external mould to show occipital ring and traces of glabellar furrows. 9, 13, Km 565 c, external mould and latex cast of most complete specimen showing form of ocular and fixigenal ridges, and thoracic segments. 12, Km 565 b, internal mould of same individual. 10, 11, Km 566 e, external mould and latex cast of incomplete cephalon to show course of facial suture, and posterior portion of free cheek with genal angle.

Fig. 3. *Pardailhania hispida* (Thoral). Lower Acadian, Route de St. Jean de Pardailhan, Coulouma, Hérault, France. In. 42020, external mould of incomplete cranidium showing transverse arrangement of tubercles on glabella. Ocular ridge not well developed.

Figs. 5, 6. *Pardailhania granieri* (Thoral). Lower Acadian, Vigne de Cauquil, Coulouma, Hérault, France. In. 49479, latex cast and external mould of cranidium showing fusion of tubercles on glabella to form transverse ridges, and strong development of ocular and fixigenal ridges as in the Turkish specimens above.

Fig. 8. Agnostid gen. and sp. indet. Km 566 b, poorly preserved internal mould of cephalon. Horizon and locality as fig. 1.



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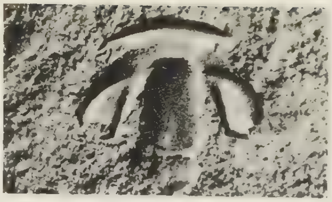

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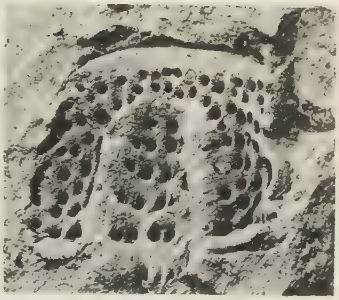

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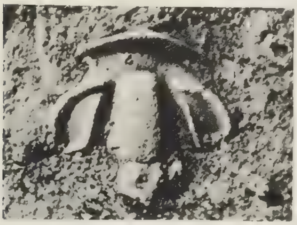

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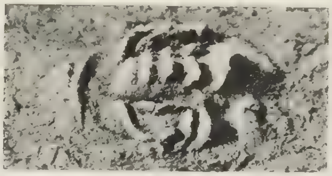

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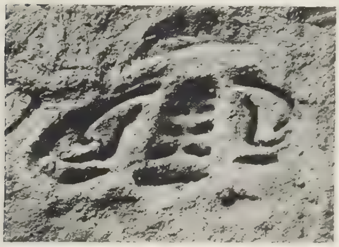

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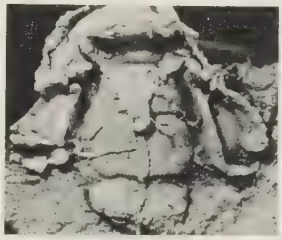

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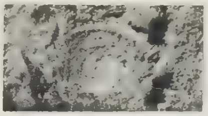

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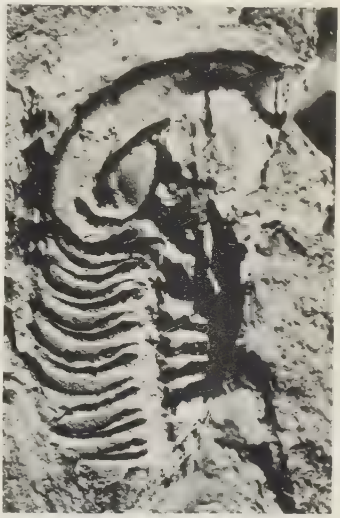

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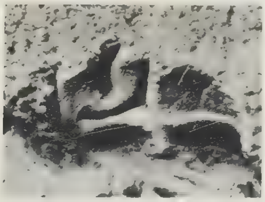

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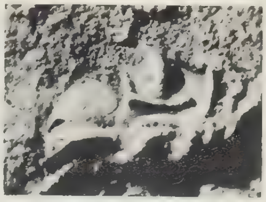

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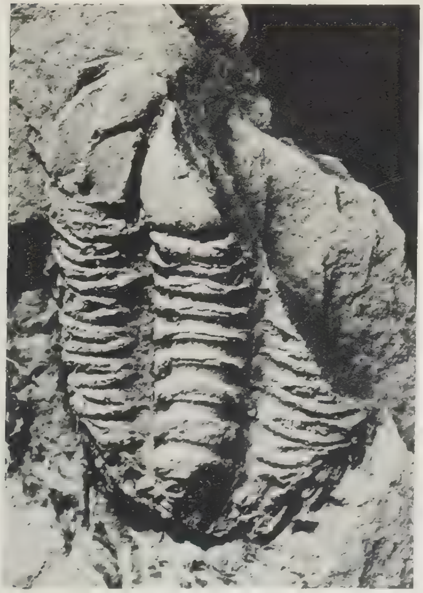

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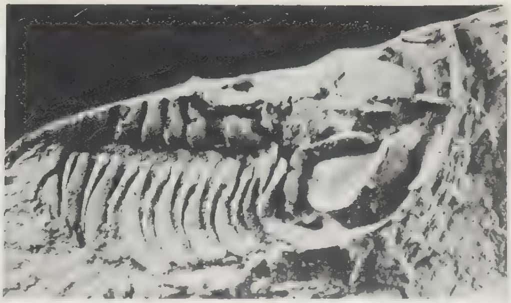

13 × 2·9

DEAN and KRUMMENACHER, *Pardailhania*

steeply, in outline convex longitudinally, and thickening medially. Occipital furrow moderately deep and transversely straight; occipital ring convex, fairly long (*sag.*) becoming shorter (*exsag.*) towards the axial furrows. Immediately outside the axial furrows the posterior border is strongly convex, becoming narrower (*exsag.*) and less well developed abaxially until it meets the blunt genal angles.

None of the specimens has the eyes preserved. Each fixigena carries a pronounced ocular ridge which commences at the axial furrows, slightly behind the line of the preglabellar furrow, arches abaxially and backwards until, opposite the mid-point of the glabella, it turns adaxially slightly and then ends abruptly about in line with the basal glabellar furrows, when the latter are visible. In the best-preserved specimens each ocular ridge is seen to be thin and vertical frontally, becoming less steep posterolaterally and at the same time thickening slightly so as to form an overhanging palpebral lobe (see Pl. 10, fig. 13). On its adaxial side the ocular ridge is bounded by a faint palpebral furrow in the vicinity of the eye. Just to the rear of the junction of each ocular ridge and axial furrow, another ridge of similar height and thickness begins. There seems to be no suitable term in use for such a structure, and Professor Whittard has suggested (*in litt.*) that the name 'fixigenal ridge' be employed. At first each fixigenal ridge runs backwards and slightly abaxially, parallel to and bordering the axial furrow, but just before reaching the pleuroccipital furrow it turns abaxially through about 110 degrees and extends laterally, almost straight and parallel to the furrow, reaching a point a short distance adaxially from the lateral border, where it is truncated by the posterior branch of the facial suture (see Pl. 10, figs. 10, 11). As already stated, the eyes are not preserved but it is possible to determine their extent from the position of the facial suture. Anterior branches run straight forwards for a short distance from the posterolateral end of the ocular ridges, and then become slightly sigmoidal, curving first abaxially and finally forwards again to intersect the anterolateral margins. Posterior branches extend abaxially and slightly backwards from the rear ends of the ocular ridges and then curve sharply backwards, first to truncate the outer ends of the fixigenal ridges and then to cut the posterior margin of the cephalon a short distance adaxially from the genal angles. The posterior margin of the cephalon between the facial suture and the genal angle is straight and cut forwards obliquely to the blunt genal angle. The free cheeks thus differentiated are small.

Dorsal surface of the exoskeleton in all the available specimens is smooth. Hypostome unknown.

One specimen (Pl. 10, figs. 9, 12, 13) possesses at least nine thoracic segments but is so badly preserved that it is impossible to determine the total number present. Each segment has a moderately long (*sag.*) axial ring which curves forwards slightly at either end towards the axial furrows to form small axial nodes. Large articulating half-ring separated from axial ring by broad (*sag.*), deep, articulating furrow. Each pleura curves gently rearwards from the axial furrow, and then forwards, terminating in a broad, rounded tip (see Pl. 10, fig. 13). Pleura divided into two bands of unequal size, of which the anterior is the smaller, by deep pleural furrow which, commencing at the axial furrow in a median position, runs abaxially and at the same time draws nearer to the anterior margin of the pleura, finally dying out without reaching the tip. Dorsal surface smooth like that of the cephalon.

Pygidium unknown.

Locality and horizon. All the Turkish specimens described and figured in this account are from the road leading to the Alan Plateau above Saylak, 12 kilometres north-north-east of Kirikhan, Province of Hatay, Turkey (see Fig. 1). No associated fossils have been found which might indicate a precise horizon within the Middle Cambrian, or Acadian, but by analogy with material from southern France the age of the fauna is probably Lower Acadian.

As originally described by Mansuy (1922) *Pardailhania barthouxi* is a member of a fauna which includes also a *Paradoxides* said to be *P. rugulosus* Hawle and Corda, though this is possibly a misidentification. According to Strand (1929, pp. 314–15, 337, 350) the latter species is characteristic of Stage 1c δ (equivalent to the Zone of *Paradoxides davidis*, Middle Cambrian) of Norway, and a similar horizon is listed by Cobbold and Pocock (1934, pl. 39) for other successions. The Turkish and Moroccan specimens are probably older.

Figured specimens. Pardailhania cf. *barthouxi*, Km 565 b (Pl. 10, fig. 12), Km 565 c (Pl. 10, figs. 9, 13), Km 565 d1 (Pl. 10, fig. 1), Km 565 d2 (Pl. 10, figs. 2, 4), Mm 565 d3 (Pl. 10, fig. 7), Km 566 e (Pl. 10, figs. 10, 11). All these specimens are in the collections of the N. V. de Bataafsche Petroleum Maatschappij, Gravenhage, Netherlands.

The two cranidia of other species figured for comparison with the above are as follows: *Pardailhania hispida*, In. 42020 (Pl. 10, fig. 3); *Pardailhania granieri*, In. 49479 (Pl. 10, figs. 5, 6). Both specimens are in the British Museum (Natural History), London.

Discussion. The genus *Pardailhania* was founded by Thoral (1947, p. 60) on his earlier described species *Solenopleura? hispida*, from the Lower Acadian of Coulouma, Hérault, southern France, and used by him to include a number of species, all of Acadian age. In these the surface details of the cephalon vary considerably, ranging from forms in which the glabella carries tubercles arranged in transverse rows, or even fused together into transverse ridges, to others in which the surface of the glabella is smooth. Although the type-species was later described by Thoral (1948, pp. 52–55) as possessing both genal and occipital spines, in the present paper *Pardailhania* is considered to include also species lacking these features, a course followed by Thoral (1947) in his original diagnosis. Generally speaking, the species usually assigned to the genus fall into two groups as follows:

Group A. Surface of glabella ornamented with tubercles arranged in transverse rows or fused together to form transverse ridges separated by a smooth, longitudinal, median band as in the related genus *Sao*. Pair of ocular ridges usually well developed; sometimes a pair of fixigenal ridges present. Species include *P. hispida* (Thoral), *P. granieri* (Thoral), *P. multispinosa* Thoral, and *P. hispanica* Sdzuy *ex* R. and E. Richter MS.; *P. couloumana* (Miquel) may also belong here. All these species are easily distinguished by their ornate cephala from the Turkish specimens, and the first two listed above are figured here for comparison (Pl. 10, figs. 3, 5, 6).

Group B. Surface of glabella smooth, occasionally showing three or four poorly defined pairs of glabellar furrows. Pair of ocular ridges and, generally, one pair of fixigenal ridges well developed, though one species *P. paschi* Sdzuy, probably belonging here, has three pairs of fixigenal ridges, two of them small. Species include *P. tenera* (Hartt), *P. barthouxi* (Mansuy), and *P. paschi.*

The trilobite determined by G. and H. Termier (1950, p. 25, pl. 204, fig. 21) as *Pardailhania* cf. *couloumana* (Miquel) is poorly illustrated and may not belong to the genus.

Two species of North American Middle Cambrian trilobites have been referred by Shimer and Shrock (1944, p. 605) to the genus *Andrarina*, namely *A. ouangondiana* and *A. tenera*. *Andrarina*, type-species *Liostracus aculeatus* Angelin, 1854, was proposed by Raymond (1937, p. 1106) on the grounds that *Liostracus* Angelin 1854 was preoccupied by *Leiostracus* Albers 1850. This argument does not conform to the International Rules of Nomenclature and, in fact, *Liostracus* was first used by Mörch (1852, p. 26). His name was, however, an invalid emendation of *Leiostracus* Albers 1850, and as such it preoccupies *Liostracus* Angelin 1854, even though it has no validity as a generic name itself. The species *Andrarina ouangondiana* was described by Hartt (*in* Dawson 1868, p. 651) as *Conocephalites ouangondianus* but was figured for the first time by Walcott (1884, p. 37, pl. 5, figs. 4, 4*a–f*) who referred the species to *Ptychoparia*. The species appears to be a typical *Andrarina*, and Strand (1929, p. 339) has claimed that it is synonymous with *A. aculeata*. The so-called *Andrarina tenera* was also first described by Hartt (*in* Dawson 1868, p. 652) from the Saint John Formation of Portland, New Brunswick. Again the species was illustrated for the first time by Walcott (1884, pl. 5, figs. 6, 6*a*, *b*) who referred it to *Ptychoparia* and placed another species, described by Hartt (loc. cit., p. 654) as *Conocephalites neglectus* in the synonymy. There can be no doubt, however, that we are dealing with a typical *Pardailhania* of Group B as listed above. Walcott's diagrams of *P. tenera* show only the cranidium but they indicate that it differs from those of the Turkish specimens in having a more pointed glabellar outline, and a small median tubercle on the occipital ring. In addition, the largest specimen has a pair of basal glabellar furrows which meet across the centre of the glabella to form a single transglabellar furrow. The same species was redescribed as *Liostracus tener* by Matthew (1888, p. 137, pl. 1, figs. 3*a–c*) who illustrated a whole individual for the first time. The thorax of this specimen possesses fifteen segments, apparently about the same as those of the Turkish specimen described above, and an extremely small pygidium. Matthew's drawings show an even more pointed glabellar outline than do those of Walcott, with four pairs of glabellar furrows which were said to be visible only on the internal mould.

The Turkish specimens of *Pardailhania* most resemble the species first described by Mansuy (1922, p. 288, pl. 10, figs. 4*a–g*) as *Ptychoparia barthouxi* from Marakech, Morocco. All the specimens figured by Mansuy appear to be distorted by cleavage to a greater or lesser degree, but their cephala agree in all essentials with those of the Turkish material and are probably conspecific, though this cannot be certain in the absence of uncrushed specimens. The pygidium of the Moroccan species is not properly known, but the thorax consists of fifteen segments similar to those of both *Pardailhania tenera* and *P.* cf. *barthouxi* (Pl. 10, figs. 9, 12, 13).

P. paschi (Sdzuy 1958, p. 24, pl. 2, fig. 1) from the middle Murero-Schichten of Spain is easily distinguished from *P. barthouxi* by its possession of three pairs of fixigenal ridges, the two anterior pairs being small and convergent forwards, and the posterior pair comprising only transverse ridges. The carapace is smooth as in the other members of Group B, and the thoracic segments are of similar construction. The age of this species is Lower Acadian, as it has been recorded in association with *P. hispida* and *P. granieri* (Lotze 1958, p. 731).

Middle Cambrian fossils have been recorded elsewhere in Turkey from the Mardin region (Stubblefield *in* Tolum and Ternek 1952, p. 17) where the fauna includes *Paradoxides* and *Solenopleura* cf. *hispida*, indicating the presence of *Pardailhania* of Group A, though there is no record of any species of Group B.

Family AGNOSTIDAE M'Coy (s.l.)

Genus and species indet.

Plate 10, fig. 8

Only one other trilobite has been found with the specimens of *Pardailhania* cf. *barthouxi* described above. The state of preservation is extremely poor, but the fossil is figured here for the sake of completeness. It consists of the cephalon of an agnostid trilobite, about 3 mm. long and of similar breadth at the base, preserved as a damaged internal mould. Sufficient detail cannot be observed to make a firm generic determination, though numerous agnostids are known from strata of similar age in southern France (Howell 1937), some in association with *Pardailhania*, and Stubblefield (*in* Tolun and Ternek 1952, p. 17) has recorded *Peronopsis* and *Pardailhania* (= *Solenopleura* cf. *hispida*) elsewhere in Turkey.

Figured specimen. Km 566 b.

REFERENCES

BLANKENHORN, M. 1891. *Grundzüge der geologie und physikalischen geographie von Nord-Syrien.* Berlin.

COBBOLD, E. S. and POCOCK, R. W. 1934. The Cambrian area of Rushton (Shropshire). *Phil. Trans. Roy. Soc. Lond.*, B **223**, 305–409, pl. 38–45.

DAWSON, J. W. 1868. *Acadian Geology. The geological structure, organic remains and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island.* 2nd ed. London.

DUBERTRET, L. 1953. Note explicative de la feuille au 200.000 'd'Antioche'. *Institut Géographique National*, Paris.

FRECH, F. 1916. Geologie Kleinasiens im Bereich der Bagdadbahn. *Zeit. deutsch. geol. Ges.* **68**, 1–325, pl. 1–24.

HOWELL, B. F. 1937. Cambrian and Ordovician trilobites from Hérault, southern France. *J. Paleont.* **9**, 222–38, pl. 22–23.

LOTZE, F. 1958. Zur stratigraphie des Spanischen Kambriums. *Geologie*, **7**, 727–50.

MANSUY, H. 1922. Déscription de quelques trilobites du Cambrien du Maroc. *Bull. Soc. géol. France*, **22**, 285–90, pl. 10.

MATTHEW, G. F. 1888. Illustrations of the fauna of the St. John Group. No. 4. *Trans. Roy. Soc. Canada*, **5** (4), 115–66, pl. 1–3.

MOORE, R. C. 1959. *Treatise on Invertebrate Paleontology.* Part O. New York.

MÖRCH, O. A. L. 1852. *Catalogus Conchyliorum quae reliquit D. Alphonso d'Aguirra & Gadea Comes de Yoldi, Regis Daniae cubiculariorum princeps, ordinis Dannebrogici in prima classe & ordinis caroli terth eques.* Hafnia.

POULSEN, C. 1954. Attempt at a classification of the trilobite family Solenopleuridae. *Meddel. Dansk. geol. Foren.* **12**, 442–7.

RAYMOND, P. E. 1937. Upper Cambrian and Lower Ordovician trilobita and ostracoda from Vermont. *Bull. Geol. Soc. Amer.* **48**, 1079–146, pl. 1–4.

SDZUY, K. 1958. Neue trilobiten aus dem Mittelcambrium von Spanien. *Senckenbergiana Leth.* **39**, 235–53, pl. 1, 2.

SHIMER, H. W. and SHROCK, R. R. 1944. *Index fossils of North America.* New York and Cambridge, Mass.

STRAND, T. 1929. The Cambrian beds of the Mjøsen district in Norway. *Norsk. geol. tidsskr.* **10,** 308–65, pl. 1, 2.

TERMIER, G. and TERMIER, H. 1950. Paléontologie Marocaine. 2, *Actual. Sci. Industr.* **1095**. Paris.

THORAL, M. 1947. Trois nouveaux genres de trilobites acadiens du Languedoc et d'Espagne. *Comptes Rend. Séances Acad. Sci.* **224,** 59–60.

—— 1948. Solenopleuridae et Liostracidae Languedociens. *Ann. Univ. Lyon, C, Sci. Nat.* **5,** 1–89, pl. 1–6.

TOLUN, N. and TERNEK, Z. 1952. Notes Géologiques sur la Région de Mardin (Résumé). *Bull. Geol. Soc. Turkey*, **3** (2), 15–19.

WALCOTT, C. D. 1884. On the Cambrian faunas of North America. Preliminary Studies. *Bull. U.S. Geol. Surv.* **10,** 281–354, pl. 1–10.

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THE SEXUAL ORGANIZATION OF CRETACEOUS *PERMOCALCULUS* (CALCAREOUS ALGAE)

by G. F. ELLIOTT

ABSTRACT. *Permocalculus ampullacea* Elliott, from the lower part of the Lower Cretaceous of Algeria and Iraq, is believed to be based on plants of the sexual generation of the botanical species, including female plants; and associated fossils are interpreted as representing both male and asexual plants, so indicating a sexual organization like that of the comparable living chaetangiacid alga *Galaxaura*.

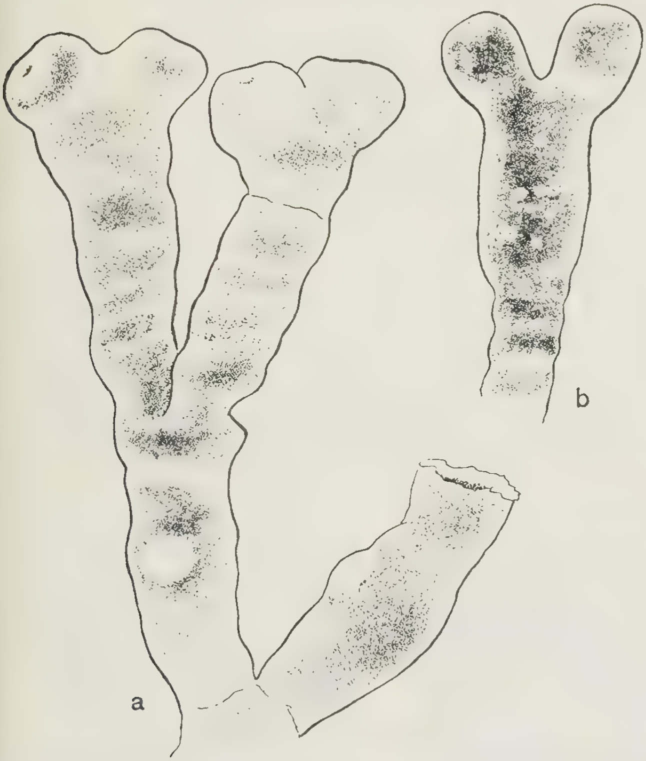
IN the living marine chaetangiacid alga *Galaxaura* separate individuals are either of dioecious sexual plants or asexual plants: the two categories are often morphologically dissimilar, and were originally classified as different taxonomic sections of the genus. Howe (1917, 1918) assumed from this that the two were related on the basis of an alternation of generations. The recognition of sexual and asexual forms of the same species has, however, proved very difficult, and in spite of very detailed studies Svedelius (1953) concluded that only by experimental spore-culture could such a relationship be definitely established. For this reason the writer (Elliott 1956, 1960), dealing with largely fragmentary remains of the extinct alga *Permocalculus*, similar to *Galaxaura*, stressed the impossibility of classifying these fossils other than on a strictly morphological basis. From the Cretaceous of Iraq three such species were described, distinguishable on average typical pore-diameter, size and shape of whole segments, and the nature of typical fragments, which depends on calcification and size of segment. These species (Elliott 1956, 1958, 1959) are *P. ampullacea* (Valanginian–Hauterivian), *P. inopinatus* (Barremian–Aptian), and *P. irenae* (Albian–Cenomanian). The present note deals primarily with the first of these.

Remains of Permocalculus ampullacea Elliott. This species occurs in north Iraq from the Jurassic–Cretaceous passage level through Valanginian and Hauterivian, as evidenced by its occurrence in the local Zangura, Garagu, Lower Sarmord, and Lower Qamchuqa formations of various deep wells in the Mosul and Kirkuk areas. In Algeria the species also occurs at these Lower Cretaceous levels.

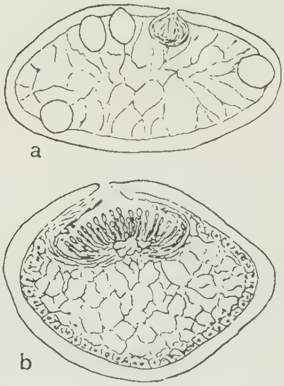
As described from the type material (Elliott 1959), *P. ampullacea* is a species of 'waxing-and-waning' morphology, roughly circular in cross-section, with variable calcification, and fine surface pores of about 0·012 mm. diameter (Pl. 11, fig. 1). Occasional specimens show scattered internal sporangial cavities (fig. 4). Associated commonly with it are fragments and debris of a much more coarsely pored but thin-walled form, with pore-diameter of 0·025–0·040 mm. (fig. 4). This has not yet been found as a complete segment, but certain pieces suggest that the segments were probably circular in cross-section. Also, rarely, there are associated remains of peculiar structures, flattened in cross-section, showing very numerous crowded cavities, smaller in size than the sporangial cavities of *P. ampullacea* s. str.; the mesh between these cavities is sometimes partly disintegrated (figs. 2, 3).

[Palaeontology, Vol. 4, Part 1, 1961, pp. 82–84 pl. 11.]

Comparison of Galaxaura and Permocalculus. Now in living *Galaxaura* the reproductive cavities (cystocarps) of female plants of the sexual generation are scattered in segments of the plant which are more or less rounded in cross-section (text-figs. 1*a*, 2*b*), and which are mechanically as stout as other segments. In the male plants, however, the cavities are smaller than in the female, and crowded in special, rather fragile, terminal segments which are flattened in cross-section (text-figs. 1*b*, 2*a*): these segments, after discharge of the spermatangial contents, probably drop off (Svedelius 1953, p. 17) and are replaced by proliferation shoots. In the asexual plants the little tetraspores are borne amongst the coarse threads or hairs of the surface, and leave no reproductive cavities in the subdermal calcification comparable with those of the sexual plants.



TEXT-FIG. 1. *Galaxaura glabriuscula* Kjellm. Recent; ×4. *a*, Female branch with cystocarps; *b*, male branch with spermatangial cavities. After Svedelius (1953).



TEXT-FIG. 2. *Galaxaura glabriuscula* Kjellm. Recent; ×23. Cross-sections of *a*, male branch; *b*, female branch. After Svedelius (1953).

It is therefore suggested that *Permocalculus ampullacea* as described is based on plants of the sexual generation of the botanical species, female when the sex is recognizable; that the rare structures described above represent reproductive segments from male plants; and that the abundant coarsely pored debris is from the asexual plants. The analogies on size and arrangement of cavities, and on the form of the containing segments, already indicated above between sexual *Galaxaura* and *Permocalculus*, are supported by the rarity of the fragile spent male structures, shed before the break-up of the whole plant which provides most of the debris for fossilization, and by the very coarsely pored presumed asexual debris. For as already stated, the asexual plants of *Galaxaura* differ markedly in appearance from the sexual ones, and the coarsely pored thin subdermal calcification in the fossil *Permocalculus* is what one would expect from a hairy rough-surfaced plant, such as is known in *Galaxaura*. It may also be of significance that Howe (1917, p. 622) records that in dried herbarium specimens of the Recent *Galaxaura* only the single superficial cell-layer exfoliates in sexual plants, whereas in the asexual plants two outer cell-layers come away. Possibly this mechanical consequence of cell-structure correlates with the differentiated fragmentation seen in the fossils.

This tripartite association has not yet been seen in the later Cretaceous species, *P. inopinatus* and *P. irenae*. This may be remedied by future collecting, but an alternative explanation is possible. Svedelius (1953, pp. 10, 50) has indicated the possibility of various Recent *Galaxaura spp.* being able to exist without alternation of generations, either solely in the sexual phase or solely as spore-producing individuals. Algae are primitive plants, and it may well be that the evolution of *Permocalculus* during the Cretaceous included a simplification of reproductive mechanism.

Acknowledgements. I am grateful to Mrs. Y. M. Butler, in charge of marine algae at the British Museum (Natural History), Dept. of Botany, with whom I discussed the observations set out here; to M. J. Emberger, of Algiers, who sent me comparison-material from the North-African Cretaceous; and to the Management of Iraq Petroleum Company, Ltd., for permission to publish this note. The text figures are reproduced by courtesy of the Royal Society of Sciences of Uppsala.

REFERENCES

ELLIOTT, G. F. 1956. *Galaxaura* (calcareous algae) and similar fossil genera. *J. Wash. Acad. Sci.* **46**, 341–3.

—— 1958. Algal debris-facies in the Cretaceous of the Middle East. *Palaeontology*, **1**, 254–9, pl. 45–48.

—— 1959. New calcareous algae from the Cretaceous of Iraq. *Rev. Micropaléont.* **1**, 217–22, 2 pl.

—— 1960. Fossil calcareous algal floras of the Middle East. *Quart. J. geol. Soc. Lond.* **115**, 217–32.

HOWE, M. A. 1917. A note on the structural dimorphism of sexual and tetrasporic plants of *Galaxaura obtusata*. *Bull. Torrey bot. Cl.* **43**, 621–4.

—— 1918. Further notes on the structural dimorphism of sexual and tetrasporic plants in the genus *Galaxaura*. *Mem. Brooklyn bot. Gdn.* **1**, 191–7, pl. 3, 4.

SVEDELIUS, N. 1953. Critical studies on some species of *Galaxaura* from Hawaii. *Nova Acta Soc. Sci. upsal.* (4) **15** (9).

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Note. Similar structures have recently been seen in *Permocalculus inopinatus* from the Barremian–Aptian of the Hadhramaut, Southern Arabia.

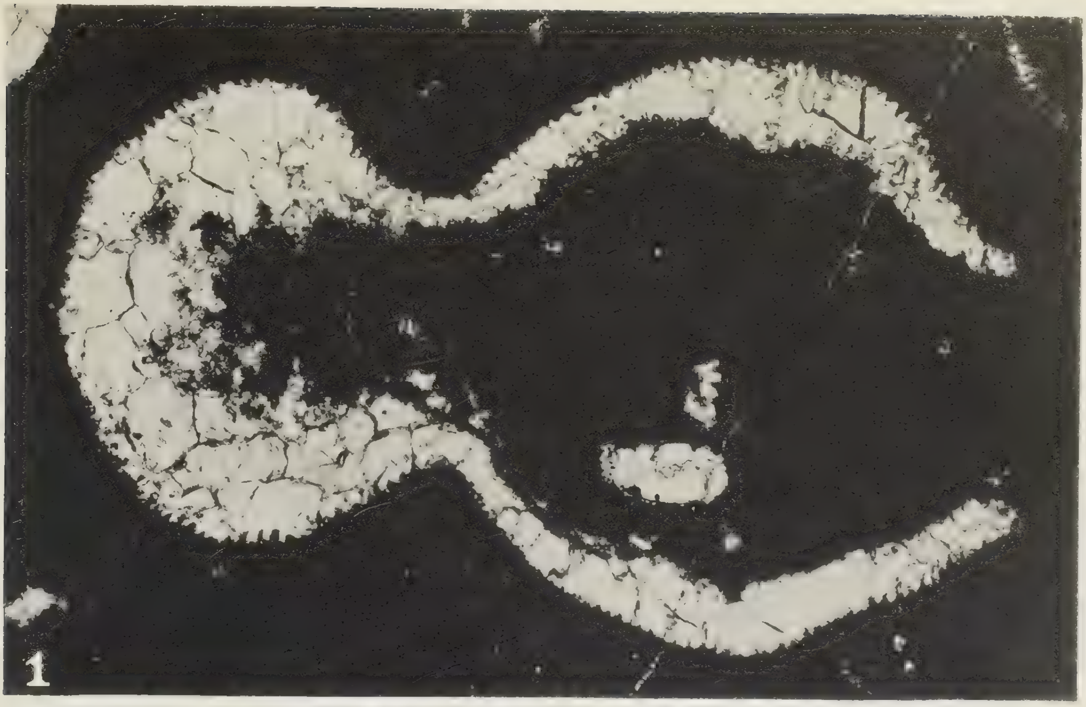
EXPLANATION OF PLATE 11

Fig. 1. *Permocalculus ampullacea* Elliott, longitudinal thin-section, ×50. Lower Cretaceous, Hauterivian; south flank of Djebel Harraza, Algeria. Brit. Mus. (Nat. Hist.) Dept. Palaeont., reg. no. V. 41663.

Fig. 2. Presumed male branch of this species, oblique-transverse thin-section, ×50. Lower Cretaceous, Hauterivian; Kirkuk well no. 116, Iraq. Reg. no. V. 41733.

Fig. 3. Presumed male branch, longitudinal thin-section, ×50. Locality and horizon as for fig. 2. Reg. no. V. 41732.

Fig. 4. Random cut showing presumed female branch with incompletely calcified sporangia on viewer's right, and fragments of coarsely pored presumed asexual form on left, ×50. Locality, horizon, and registered number as for fig. 1.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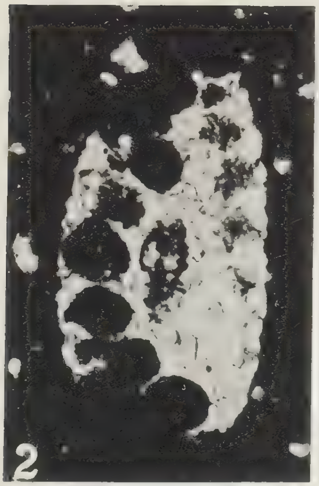
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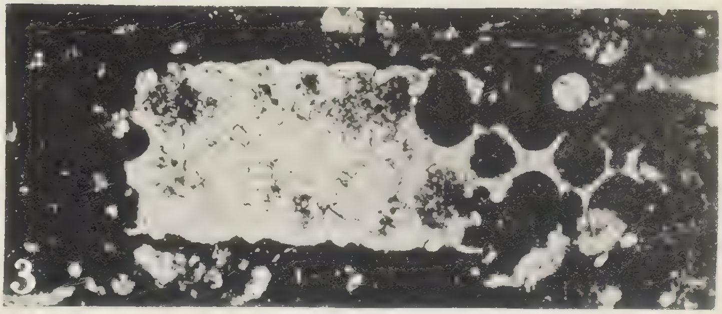
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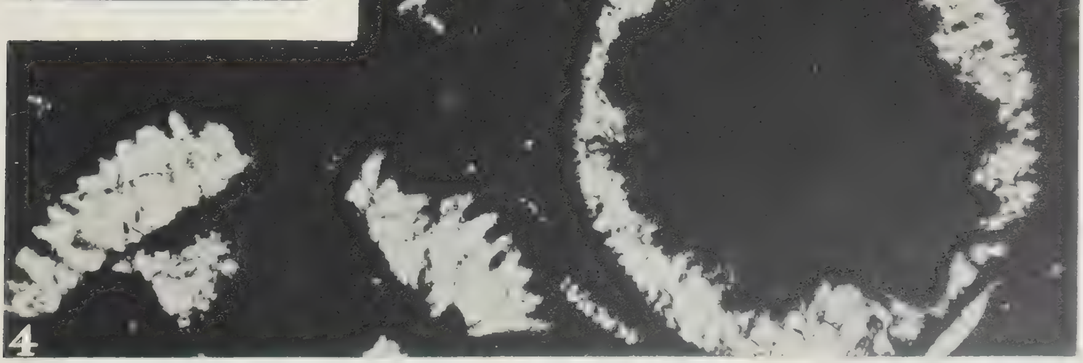
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EOCENE CRABS IN A LONDON CLAY NODULE

by J. COLLINS

ABSTRACT. The outstanding features of a number of crabs, belonging to three species, present on a single nodule from the London Clay (Upper Ypresian), are here described. Comparisons made with existing descriptions reveal certain new structures to one of the species; a new geographical recording is also made.

THIS paper describes a nodule which, although only 60 mm. in length and 40 mm. at its broadest part, contains no less than twelve individual crabs visible on its surface. All the specimens, which are casts, are preserved with their original convexity and represent three species: *Campylostoma matutiforme* Bell, *Laeviranina gottschei* (J. Böhm), and *Mithracia libinioides* Bell. *C. matutiforme* is the most prolific, there being seven examples, all juveniles; whereas of the other two species, each represented by one example, *L. gottschei* may by comparison with other specimens—in the British Museum (Natural History)—be regarded as approaching the adult stage, and *M. libinioides* (Pl. 12, figs. 3, 3*a*) as being an adult. The remaining three specimens are obscured by matrix and are indeterminable.

Occurrence. London Clay (Upper Ypresian), Lower Eocene, Isle of Sheppey. The nodule is now in the University Museum, Oxford, the individual specimens being numbered L55 to L66.

Campylostoma matutiforme Bell

Plate 12, figs. 1, 1*a*

Although the specimens (L55–L61) are juveniles, they show to a marked degree the characteristics of the adult; they are, however, rather more rounded in outline.

The five antero-lateral spines (of which the external-orbital forms the first) are well developed, and although no one specimen is entire a sound composite conception may be formed of their structure. The second to fourth pairs are about the same size, triangular in outline, rounded above and slightly upturned. The fifth is considerably more robust and is produced to a length almost equal to three-quarters of the carapace width at the base of these spines. The spine projects at right angles to the antero-lateral margin and is granulated like the carapace. Its borders are parallel for almost half the length, after which the anterior border, armed with five or six spinules, curves back towards the apex.

On the specimens examined by Bell (1857) this spine had been broken off close to the carapace, and although he thought it might have been produced into a long spine, he claimed that the short length of spine preserved in one individual (1857, pl. 3, fig. 9) was hypertrophied. This diagnosis has led to some misrepresentation of the outline of this species and it has been figured (e.g. Salter and Woodward 1865) with all the antero-lateral spines of nearly equal size. Measurements (taken from the most complete example, L55): length, along median line, 13·3 mm.; width, anterior to fifth spine, 13·9 mm. Total width, including fifth spine, *c.* 32·0 mm.

[Palaeontology, Vol. 4, Part 1, 1961, pp. 85–86, pl. 12.]

Laeviranina gottschei (J. Böhm)

Plate 12, figs. 2, 2*a*

Coming as it does from the Isle of Sheppey the geographical range of this rare species, hitherto recorded in Britain from Herne Bay, Highgate, Oxshott (Brown and Castell 1954), and Tolworth, is yet further extended. Measurements (L62): length, along median line, 15·9 mm.; width, 10·5 mm.

Acknowledgements. Sincere thanks are due to Mr. J. M. Edmonds of the University Museum, Oxford, for kindly loaning the nodule for examination; to the Officers of the British Museum (Natural History) for providing access to specimens; and to Mr. E. J. Kentish who prepared the photographs.

REFERENCES

BELL, T. 1857. Fossil Malacostracous Crustacea of Great Britain. *Palaeontogr. Soc.*

BÖHM, J. 1918. Über *Raninoides gottschei* n. sp., aus dem Eocän von Hemmoor. *Z. deuts. geol. Ges.* **70,** Monatab. 35.

—— 1922. *In* K. Martin, Die Fossilien von Java, Bd. i, Abt. 2, Hft. iv Arthropoda, Crustacea. *Samml. geol. Rchmus. Leiden*, N.F., **1,** 251–535, pl. 63.

—— 1927. *Raninellopsis gottschei* nov. gen. n. sp. *Jahrb. preuss. geol. Landesanst.* **48,** 563–6.

BROWN, M. M. and CASTELL, C. P. 1954. Additions to the London Clay Fauna of Oxshott, Surrey. *London Naturalist*, **34,** 47.

GLAESSNER, M. F. and WITHERS, T. H. 1931. On London Clay Crabs of the family Raninidae. *Ann. Mag. Nat. Hist.* (10), **8,** 47.

SALTER, J. W. and WOODWARD, H. 1865. *Catalogue and Chart of Fossil Crustacea.* London.

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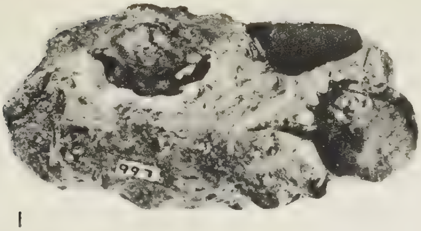
EXPLANATION OF PLATE 12

Fig. 1. The nodule (×1) showing dorsal view of *Campylostoma matutiforme* (L55) and left lateral view of *Laeviranina gottschei*. The anterior part of another *C. matutiforme* may also be seen. 1*a*, Portion of fig. 1 enlarged, ×2.

Fig. 2. The nodule (×1) showing dorsal view of *L. gottschei* and frontal view of *C. matutiforme* (L55). 2*a*, Portion of fig. 2 enlarged, ×2.

Fig. 3. The nodule (×1) showing the carapace of *Mithracia libinioides*; the right lateral margin of *L. gottschei*, part of specimen L55 (at the top of the photograph) and several other examples of *C. matutiforme* may also be seen. 3*a*, Portion of fig. 3 enlarged, ×2.

Eocene, Upper Ypresian, London Clay, Isle of Sheppey.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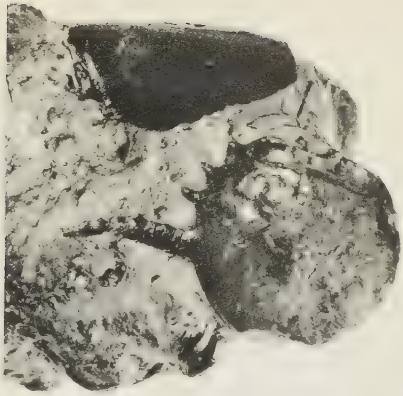
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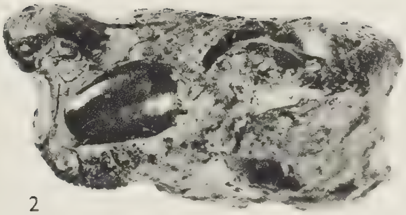
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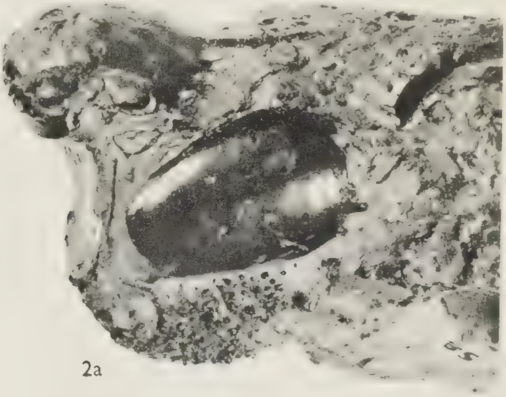
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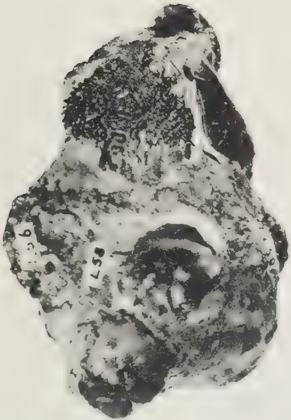
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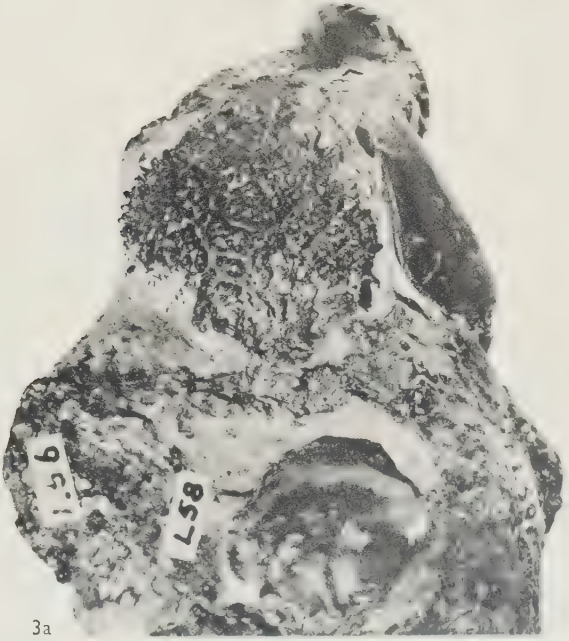

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COLLINS, Eocene crabs

NEW RHAETIC AND LIASSIC BEETLES

by B. G. GARDINER

ABSTRACT. An isolated coleopteran elytron from the Lower Lias of Lyme Regis is described and named *Elaterina liassica* gen. et sp. nov. Six fragments of coleoptera including five pieces of elytra and one metasternum were collected from a fissure of Rhaetic age in the Carboniferous Limestone of South Wales. Their relationship with the present-day Cupedidae is considered and the fragments have been named *Metacupes harrisi* gen. et sp. nov.

ALL except one of the present insects were discovered as a result of a programme of field work which has been carried out in South Wales for the past eight years by Dr. K. A. Kermack of University College, London, and his co-workers (Kermack and Mussett 1958). Professor T. Harris of Reading, while investigating the plants (Harris 1957) from a fissure in Cnap Twt quarry near Bridgend, found a number of insect fragments which he kindly put at my disposal for description. At first sight the colour and nature of much of the matrix in many of the fissures in the Bridgend area suggest the age to be Keuper (Kermack, Kermack, and Mussett 1956), although Harris (1957) from the contained flora suggests that it is Upper Rhaetic or Basal Lias in age. This apparent discrepancy is explained by a recurrence in the Rhaetic of conditions similar to those under which the Keuper Marls were deposited. In several places west of Bridgend the Rhaetic shows an interbedding of some thin bands of red and green marls indistinguishable from the Keuper Marl in the upper part of the *Pteria* (*Avicula*) *contorta* zone (Strahan and Cantrill 1904).

The last of these insects was discovered while preparing in acetic acid a specimen of *Osteorachis macrocephalus* Egerton from the Lower Lias of Lyme Regis. The elytron of a beetle was found within the orbit of this fish.

SYSTEMATIC ACCOUNT

Family ELATERIDAE Eschsholtz 1829

Genus ELATERINA gen. nov.

Type species. Elaterina liassica gen. et sp. nov., Lower Lias, Lyme Regis.

Diagnosis. An elaterid with its elytron bluntly rounded posteriorly and with a distinct groove running round both lateral edges.

Elaterina liassica gen. et sp. nov.

Text-fig. 1

Holotype. British Museum (Nat. Hist.) IN 50351, Lower Lias, Lyme Regis.

Diagnosis. The elytron measures 12·5 mm. in length and 5 mm. at its widest point. Posteriorly slender striations run about one-quarter of the length of the elytron. The ornamentation consists of minute raised tubercles which cover the entire dorsal surface.

Remarks. From a comparison with figures published in Bode (1953) and with living

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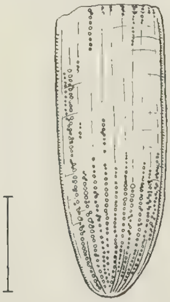
species, the elytron is that of a beetle very similar in structure to the present-day Elateridae (click beetles). Since, however, there is no one genus with which it corresponds more than superficially, I propose to designate it by a new name (*Elaterina liassica*, gen. et sp. nov.).

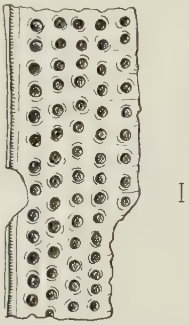
Family CUPEDIDAE Lacordaire 1857

Genus METACUPES gen. nov.

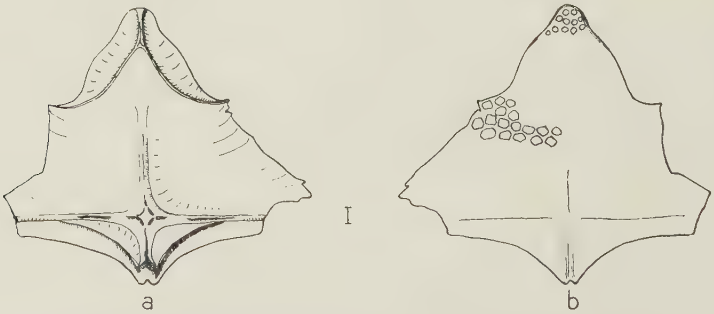
Type species. Metacupes harrisi gen. et sp. nov., Rhaetic, Bridgend.



TEXT-FIG. 1. *Elaterina liassica*, n. gen. et n. sp. B.M. N.H. IN 50351, Lower Lias, Lyme Regis. Scale represents natural size.



TEXT-FIG. 2. *Metacupes harrisi*, n. gen. et n. sp. B.M. N.H. IN 50352, fragment of elytron, Rhaetic, Bridgend.



TEXT-FIG. 3. *Metacupes harrisi*, n. gen. et n. sp. B.M. N.H. IN 50352, Rhaetic, Bridgend. Metasternum in *a*, dorsal view; *b*, ventral view.

Diagnosis. Elytron with a deeply punctate, regularly arranged ornamentation. Metasternum triangular and with characteristic strengthening bars on its inner surface.

Remarks. The insect remains collected from the fissure near Bridgend numbered six fragments. Of these five were pieces of elytra, and the sixth a metasternum of a beetle.

Metacupes harrisi gen. et sp. nov.

Text-figs. 2, 3

Holotype. British Museum (Nat. Hist.) IN 50352, Rhaetic, Cnap Twt quarry, near Bridgend.

Diagnosis. The fragments of elytra are all similar. The largest piece shows a distinct groove running down one of its lateral edges (text-fig. 2) and has a deeply punctate, regularly arranged, ornamentation (areolate).

The metasternum measures 2·2 mm. in length and its general shape is given in text-fig. 3. It is roughly triangular and strengthened on its inner surface by two bars, which together form a cruciform structure. The locations of these strengthening bars are apparent on the external surface. The ornamentation consists of a tuberculate sculpturing.

Remarks. At first sight these few remains (B.M. N.H. IN 50352 and IN 50353) appear too fragmentary to identify with certainty, however the metasternum is probably a more diagnostic character than the elytron, and the only living family I have observed possessing a metasternum of this shape is the Cupedidae.

Rohdendorf (1958) has recently figured many new and interesting forms of fossil Coleoptera from the Permian of Siberia. One of these *Protocupes martynovi* Rhod. has an elytron with a very similar ornamentation to that of *Metacupes harrisi* gen. et sp. nov. With the additional evidence obtained from the metasternum there is every justification in putting the above fragments together with his in the same family, the Cupedidae.

The fragments seem to be near the living genus *Omma* Newman and very similar to a fossil genus *Mesothoris* described by Tillyard (1916).

Discussion. Since these Permian and Rhaetic members of the Cupedidae looked so much like living species of today, there must be in the younger rocks intermediates differing little from the Rhaetic forms on one hand, and the living species on the other. On examination of the appropriate collections in the British Museum (Nat. Hist.) this has proved to be the case, and Dr. R. Crowson of Glasgow University will shortly be describing many of these forms in a review of the Cupedidae.

REFERENCES

BODE, A. 1953. Die Insekten fauna des Ostniedersächsischen overon Lias. *Palaeontographica*, **103A**, (1–4), 1–375.

HARRIS, T. M. 1957. A Liasso-Rhaetic flora in South Wales. *Proc. Roy. Soc. B*, **147**, 289–308.

KERMACK, D. M., KERMACK, K. A., and MUSSETT, F. 1956. New Mesozoic mammals from South Wales. *Proc. Geol. Soc. Lond.*, no. **1533**, 31.

KERMACK, K. A. and MUSSETT, F. 1958. The jaw articulation of the Docodonta and the classification of Mesozoic mammals. *Proc. Roy. Soc. B*, **148**, 204–15.

ROHDENDORF, B. B. 1958. Les Insectes Paléozoiques du sud de la Sibérie. *Proc. 10th Internat. Congr. Ent.* **1**, 853–9.

STRAHAN, A. and CANTRILL, T. C. 1904. Geology of the South Wales coalfield. Part IV, The country around Bridgend. *Mem. Geol. Survey.*

TILLYARD, R. J. 1916. Mesozoic and Tertiary insects of Queensland and New South Wales. *Qd. Geological Survey*, **253**, 11–60.

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MICROPLANKTON FROM THE KELLAWAYS ROCK AND OXFORD CLAY OF YORKSHIRE

by W. A. S. SARJEANT

ABSTRACT. Assemblages of microplankton from the Kellaways Rock and Oxford Clay of Yorkshire are described. They consist dominantly of hystrichospheres, including new species of *Cymatiosphaera* and of *Cannosphaeropsis*. Dinoflagellates are also prominent, with *Gonyaulax jurassica* Deflandre most abundant: two new species of *Gonyaulax* are described. Organisms *incertae sedis*, probably microplankton, are present: three new genera, *Stephanelytron*, *Antrosphaera*, and *Netrelytron*, and a new species of *Wanaea* are described. The character and stratigraphic significance of the assemblages are discussed.

FOUR assemblages of fossil microplankton are dealt with here, all from the Upper Jurassic of the Yorkshire coast. The lowest horizon examined was the Kellaways Rock (*Sigaloceras calloviense* Zone), a rather sparse assemblage being obtained from a sample of calcareous sandstone 1 foot below the base of a thick argillaceous sandstone and approximately 45 feet below the base of the Oxford Clay, in the exposure in the cliff below Scarborough Castle (grid reference 053890). The Hackness Rock (*Quenstedtoceras lamberti* Zone) from the same locality was also examined: however, the sample of ferruginous oolite from the uppermost Hackness Rock yielded planty remains and abundant wood fragments, but very little pollen and no microplankton. Three horizons of the Oxford Clay (*Quenstedtoceras mariae* Zone) were examined: each sample was of grey clay, quite highly calcareous, and each yielded an abundant microplankton assemblage. The lowest horizon studied was 1 foot above the top of the Hackness Rock, exposed at the base of Scarborough Castle cliff. The other samples were from High Red Cliff, Cayton Bay (grid reference 077843), 3½ miles south-east of the previous locality, and from horizons respectively 25 feet above and between 90 and 100 feet above the top of the Hackness Rock (henceforth referred to as the '25-foot' and '100-foot' horizons).

Each sample examined was crushed mechanically, treated with hydrochloric acid to remove carbonates, then heated in hydrofluoric acid to remove silicates. The residue was then macerated in Schultz solution for periods of between 15 minutes and 1 hour, maceration time varying according to the amount of residue and its appearance on microscopic examination; the object of maceration was to remove by oxidization the bulk of plant tissues and of structureless 'humic' substances. The resultant concentrates were mounted in various fashions; polyvinyl acetate resin, Santolite, Lakeside cement, and solid and liquid Canada balsam were experimented with, but glycerine jelly was found the most satisfactory mountant. Safranin stain, mixed with the glycerine jelly, successfully stained and gave satisfactory contrast to the rather colourless microfossils, its only disadvantage being the unavoidable masking of the original colour of the microfossils.

In the mounts of Kellaways Rock material, microplankton formed only about 5 to 10 per cent. of the total microfossil assemblage, the remainder comprising spores, pollen, and the shell linings of foraminifera. The assemblage of microplankton, domi-

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nantly hystrichospheres with dinoflagellates forming only 7 per cent., described from this material was thus numerically relatively small: it proved intermediate in character between the Oxford Clay assemblage and a Cornbrash assemblage described in an earlier paper (Sarjeant 1959). The Oxford Clay mounts proved considerably richer in microplankton, the latter making up 60–70 per cent. of the total microfossil assemblage. Hystrichospheres again dominated the microplankton, but this time the dinoflagellates proved more abundant. In the lowest horizon, dinoflagellates form 20 per cent. of the microplankton; in the 25-foot horizon, 10 per cent.; and in the 100-foot horizon, 40–45 per cent. Spores and pollen form the remainder of the assemblage, with the shell linings of foraminifera very subordinate (less than 1 per cent.). There are in addition a small number of simple sacs, probably but not certainly pollen.

The fossil microplankton are on the whole very well preserved, and in damaged forms the damage seems in many cases to have occurred before fossilization. Eight species of dinoflagellates were identified, *Gonyaulax jurassica* Deflandre being the most abundant at all horizons; twenty species of hystrichospheres were distinguished; and six species of organisms *incertae sedis* but probably also microplankton. All specimens described are now in the collection of the Micropalaeontology Laboratory of the Department of Geology, University of Sheffield.

DESCRIPTION OF THE ASSEMBLAGES

Class DINOFLAGELLATA

Family GONYAULACIDAE

Genus GONYAULAX Diesing

Gonyaulax jurassica Deflandre 1938

Plate 13, figs. 1, 9–12; text-figs. 1–3

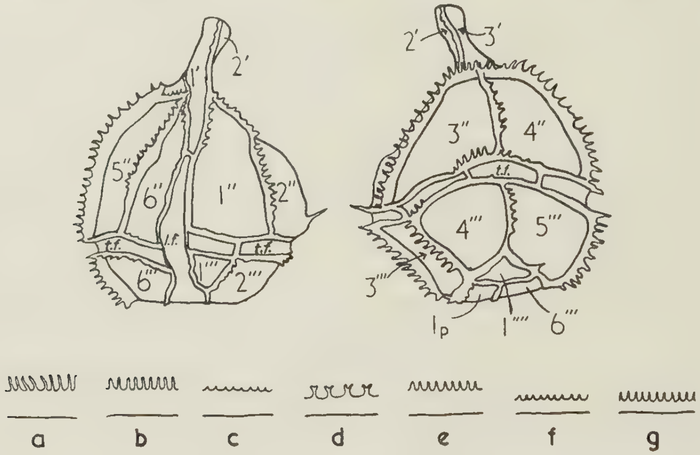
Remarks. This species, previously recorded from the Bathonian (Valensi 1953) and Oxfordian of France (1938) and from the Kimeridgian of England (Downie 1957), proved extremely abundant. Observed distribution: Kellaways Rock 4; Oxford Clay, lowest 40, 25-foot 6, 100-foot 79. Of these, six have been attributed to Deflandre's variety *longicornis* (see later).

The tabulation corresponds in its general features with that described by Deflandre. Plate 1‴, however, shows some variation in shape: in all specimens from the lowest and 25-foot horizons of the Oxford Clay where this plate can be clearly seen, its shape is triangular (the figured specimen CB56/11/29 shows this well). In specimens from the Kellaways Rock and highest Oxford Clay by contrast, plate 1‴ was reduced and elongate as in the type. The significance of this variation remains obscure.

Considerable variation is exhibited in height and degree of denticulation by the crests on sutures, seven principal variations being noted (see text-fig. 1). All were observable in specimens from the lower horizons, variation *d* being displayed by only one specimen (SC2/31/2). However, variation in specimens from the 25-foot and highest Oxford Clay horizons was restricted to types *a*, *b*, or *c*, i.e. high crests with widely spaced, slender denticles of varying height. Deflandre has commented on the extreme variability of general form in *G. jurassica*, noting all intermediates from specimens with convex flanks to others with concave flanks. He records a range of overall lengths from

65 to 100 μ; this corresponds closely with the range observed from these specimens (55–102 μ).

Eighty specimens from the Oxford Clay, comprising 37 specimens from the lowest, 5 from the 25-foot, and 38 from the 100-foot horizons, were measured; the accompanying graphs represent the results of this study. In the first (text-fig. 2) thecal length without crests is plotted against thecal breadth without crests. Whilst the deformability of the theca certainly affects these measurements in some degree, the result shows that increase in length is accompanied by increase in breadth, the correlation not being, however, very close. The second graph (text-fig. 3) shows overall length plotted against horn length: an increase of length of horn with increasing size is evidenced. Separate plotting of measurements of the faunas from each horizon produced no indication of differences between horizons.



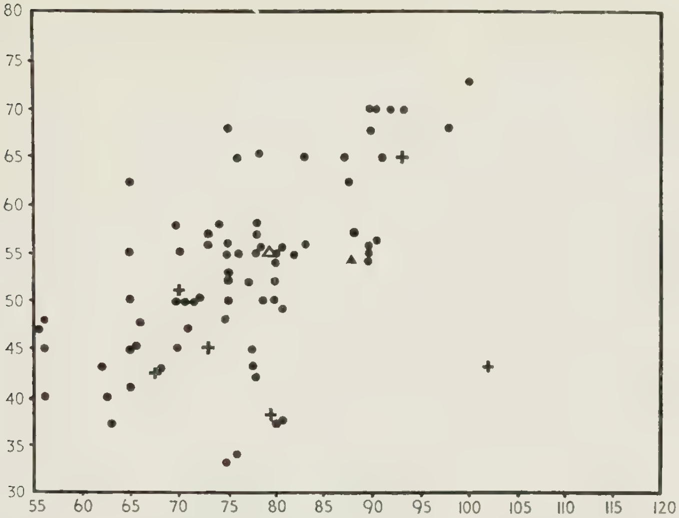
TEXT-FIG. 1. Tabulation of a specimen of *Gonyaulax jurassica* Deflandre showing a triangular plate $1'''$. Left: in ventral view. Right: in dorsal view. The specimen figured is CB56/11/29, ×600. *t.f.*, transverse furrow; *l.f.*, longitudinal furrow. Below: different forms of sutural crests developed by *G. jurassica* [based on CB81/15/12 (*a*), CB81/6/18 (*b*), CB81/12/5 (*c*), SC2/31/2 (*d*), SC2/32/16 (*e*), SC2/29/10 (*f*), and SC2/32/22 (*g*)], ×500.

Deflandre comments: '. . . stains fix in a very capricious manner'. He lists twelve stains, all of which were taken up in varying degree by his specimens and mentions carmine and safranin as tried without success. The Yorkshire specimens took up safranin very readily, emphasizing the validity of Deflandre's comment.

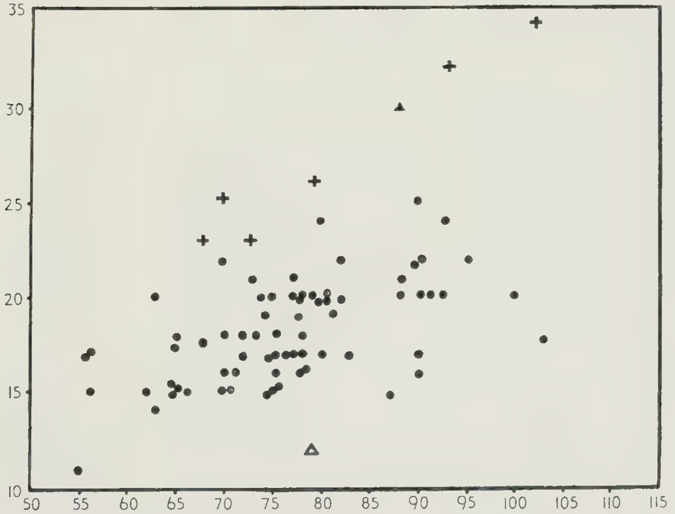
Gonyaulax jurassica var. *longicornis* Deflandre 1938

Text-figs. 2–3

Remarks. Three specimens from the lowest and three from the 100-foot Oxford Clay horizons were attributed to this variety, previously described only from the Oxfordian of France. All have a horn length at least one-third of the overall length. Their dimensions have been plotted on the graphs (text-figs. 2 and 3). On the graph on which thecal length and breadth are related they do not form any distinct group. From the second graph, where horn length is plotted against overall length, it may be seen that there is



TEXT-FIG. 2. Relationship of thecal length and breadth in *Gonyaulax jurassica*. Diagram based on an assemblage of eighty specimens from the Oxford Clay of Yorkshire. Measurements are given in μ. Δ, type of *G. jurassica*; ▲, type of *G. jurassica* var. *longicornis*; +, Yorkshire specimens of *G. jurassica* var. *longicornis*.



TEXT-FIG. 3. Relationship of overall length to horn length in *Gonyaulax jurassica*. Diagram based on an assemblage of eighty specimens from the Oxford Clay of Yorkshire. Measurements are given in μ.

no clear distinction between this variety and the normal *G. jurassica* and that these are merely forms at the extreme end of the scatter.

Gonyaulax cladophora Deflandre 1938

Plate 13, fig. 2 and Plate 14, figs. 1–2

Remarks. Deflandre's remark may be echoed: 'Although plentiful . . . this species is most often in a bad state of preservation.' Observed distribution; Kellaways Rock 2, Oxford Clay, lowest 30, 25-foot 7, 100-foot 29. Only one, specimen CB81/10/5, was sufficiently well preserved for the full tabulation to be determined (plate 2″ being missing). It is in somewhat oblique position; the dimensions given are thus taken from specimen SC2/36/4 : overall length 120 μ with apical horn *c.* 23 μ, overall breadth 100 μ, spines on crests around 8 μ high. Relatively few specimens were well enough preserved for satisfactory measurement; however, all appear to fall within the range overall length 65–125 μ. The character of the spines is as described by Deflandre except that they are always isolated and never linked at the base, as is sometimes the case in his specimens. This species has been previously recorded from the Bajocian (Mercier 1938; Valensi 1953), the Oxfordian (Deflandre 1938), and the Lower Kimeridgian (Deflandre 1941) of France.

Gonyaulax acanthosphaera sp. nov.

Plate 13, fig. 14; text-fig. 4

Holotype. SC2/32/23, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions of type.* Length 65 μ, breadth 65 μ, transverse furrow *c.* 5 μ in width. Spines on sutures *c.* 1 μ in length, spines elsewhere *c.* 0·3 μ in length. Specimen SC2/34/12 similar; other specimens too damaged for measurement.

Diagnosis. A species of fossil *Gonyaulax* having a globular theca with the tabulation ?3′, 1a, 6″, ?6‴, ?2pv, 1⁗ and without an apical horn. A dense cover of extremely short, blunt, stubble-like spines covers the entire theca, being somewhat reduced on the transverse and longitudinal furrows. Sutures between plates not raised, but ornamented

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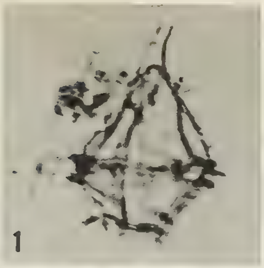
EXPLANATION OF PLATE 13

Microplankton from the Kellaways Rock of Yorkshire. All figures are ×500.

Fig. 1. *Gonyaulax jurassica* Deflandre, SC33/16/4, in dorsal view.
Fig. 2. *Gonyaulax cladophora* Deflandre, SC33/16/3, in dorsal view.
Figs. 3–4. *Micrhystridium fragile* Deflandre. 3, SC33/17/5. 4, SC33/11/5.
Fig. 5. *Micrhystridium inconspicuum* Deflandre, SC33/15/1.
Fig. 6. *Cymatiosphaera parva* Sarjeant, SC33/5/15.
Fig. 7. *Antrosphaera calloviensis* gen. et sp. nov., SC33/5/16, holotype.
Fig. 8. *Cannosphaeropsis caulleryi* (Deflandre), SC33/14/2.

Microplankton from the Oxford Clay of Yorkshire.

Figs. 9–12. *Gonyaulax jurassica* Deflandre. 9, CB81/15/12, in dorsal view. 10, SC2/33/10, in dorsal view. 11, SC2/4/29, in ventral view. 12, CB56/11/29, in oblique ventral view.
Fig. 13. *Gonyaulax areolata* sp. nov., SC2/34/21, holotype, in ventral view.
Fig. 14. *Gonyaulax acanthosphaera* sp. nov., SC2/32/23, holotype, in ventral view.
Fig. 15. *Gonyaulax sp.*, SC2/28/9.
Fig. 16. *Pareodinia ceratophora* Deflandre, CB81/6/4.
Fig. 17. *Pareodinia ceratophora* Deflandre var. *pachyceras* Sarjeant, SC2/33/25.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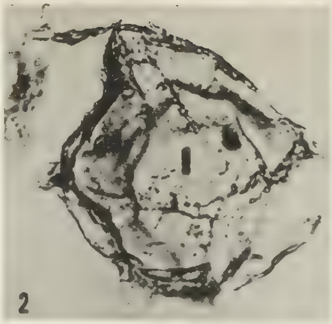
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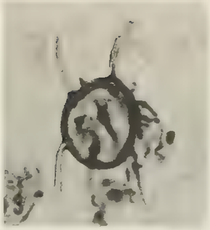
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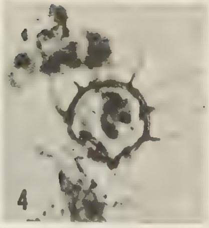
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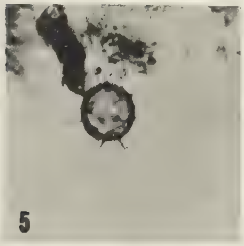
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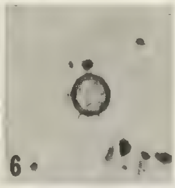
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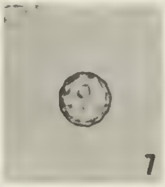
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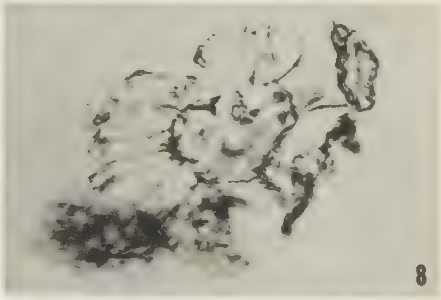
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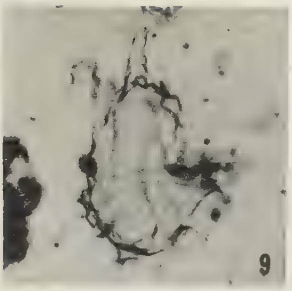
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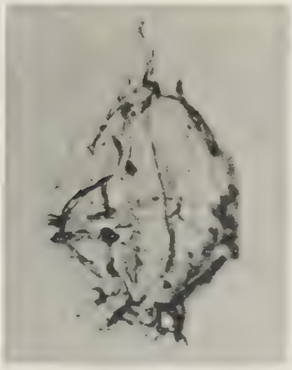

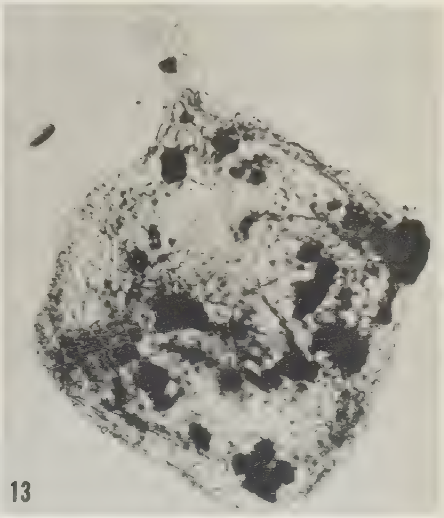
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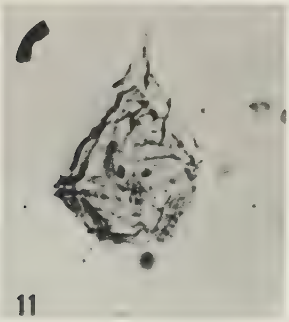
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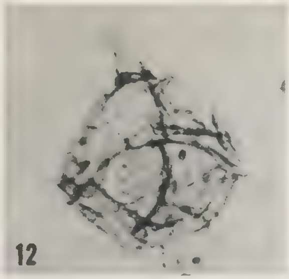
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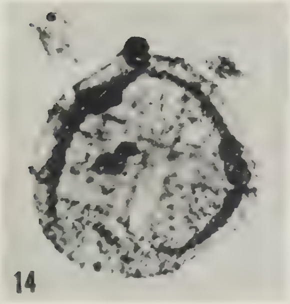
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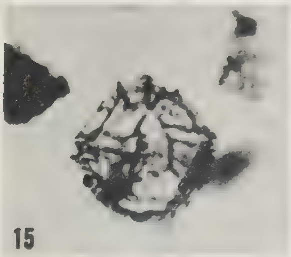
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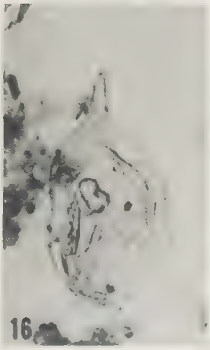
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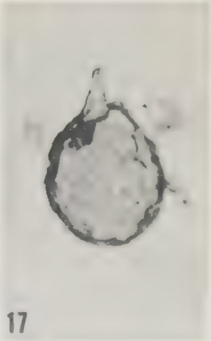
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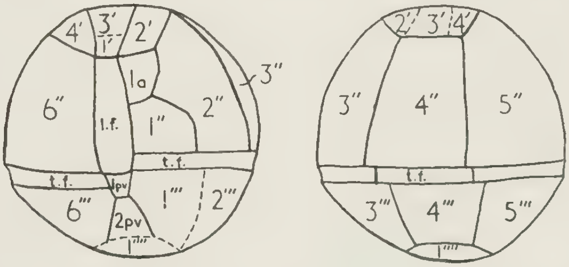
SARJEANT, Jurassic microplankton

with rows of short spinelets, some bifurcating, longer than those of the general spine cover.

Description. Theca yellowish in colour. Tabulation not easy to determine since sutures are not raised and their longer spines readily escape notice against the dense background of shorter spines. Apparently three apical plates: however, plate 1′ of type gives suggestion of possible subdivision into two. One anterior intercalary plate and six pre-equatorial plates, with plate 1″ reduced. Transverse furrow extends around theca in laevo-rotatory spiral such that its two ends differ in antero-posterior position by the furrow's width. Longitudinal furrow broad: small posterior ventral plate present, corresponding to its hypothecal extension and adjacent to the more posterior of the two ends of the transverse furrow. A second posterior ventral plate, somewhat larger in size, appears to be present between this and the polygonal antapical plate. Six post-equatorial plates present. Holotype somewhat damaged; tabulation of the dorsal surface therefore based on specimen SC2/34/12. Holotype encloses (below plate 1″) a round brownish body, apparently of organic material and with an irregular spiny margin.



TEXT-FIG. 4. Tabulation of *Gonyaulax acanthosphaera* sp. nov. Left: in ventral view. Right: in dorsal view. Figures based on the holotype SC2/32/23, and a paratype, SC2/34/12. *p.v.*, posterior ventral plate. ×500.

Remarks. It is probable that this dinoflagellate is more numerous than appears from the number of specimens recorded (six); however, other specimens seen may well have been confused with the hystrichosphere *Baltisphaeridium* cf. *fimbriatum*, abundant in this material and also having a cover of short spines. All specimens recorded were from the lowest Oxford Clay horizon.

In its spherical shape and dense spine cover *G. acanthosphaera* differs from all eight described fossil species of *Gonyaulax* lacking apical horns. It finds its closest comparison in *Palaeoperidinium castanea* Deflandre 1935 from the Cretaceous of France, a globose form with a cover of short spines, but differing from *G. acanthosphaera* by possession of a denticulate apical horn and a definitely different tabulation.

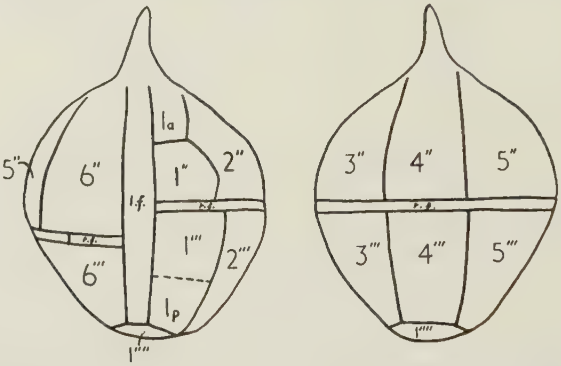
Gonyaulax areolata sp. nov.

Plate 13, fig. 13; text-fig. 5

Holotype. SC2/34/21, lowest Oxford Clay. Scarborough Castle cliff. *Dimensions.* Holotype: overall length 155 μ, length of horn 25 μ, overall breadth 125 μ; transverse furrow *c.* 10 μ wide, longitudinal furrow *c.* 5 μ wide. Range of dimensions observed: overall length 120–170 μ, relative proportions being fairly constant.

Diagnosis, A species of fossil *Gonyaulax* with an ovoid theca having the tabulation ?′, 1a, 6″, 6‴, ? 1p, 1⁗ and with a strong, tapering apical horn rounded at its extremity. The whole thecal surface except the longitudinal and transverse furrows is covered by low ridges forming an irregular reticulate patterning; the thecal wall is very thin but consists of two layers, the outer layer bearing the ridges. The boundaries of plates and the furrow margins bear low alveolate crests. The longitudinal furrow extends from apex to antapex; it is narrow, as is the transverse furrow.

Description. Theca yellowish. Tabulation not easily discerned and a composite text-figure therefore given. Apical tabulation obscure. An anterior intercalary plate clearly present, plus six pre-equatorial plates, of which the first (1″) is reduced. Transverse furrow extends around theca in a strong laevo-rotatory spiral such that its two ends differ in antero-posterior position by approximately three times the furrow's width. Six post-equatorial plates certainly present; a posterior intercalary plate appears present but could not be definitely confirmed. No posterior ventral plates present, longitudinal furrow extending to polygonal antapical plate. Surface reticulation of ridges dense; fields delimited by these ridges always small, not regularly polygonal but varying considerably in relative size and shape. Reticulation extending on to apical horn but absent from furrows. Crests consist of linked processes (links sometimes broken) arising from sutures, their points of origin corresponding with junctions of ridges with sutures.



TEXT-FIG. 5. Tabulation of *Gonyaulax areolata* sp. nov. Left: in ventral view. Right: in dorsal view. Diagrammatic, based on the holotype SC2/34/21 and on several paratypes. ×300.

Remarks. Observed distribution: Oxford Clay, lowest 9, 100-foot 15. Not recorded from the Kellaways Rock.

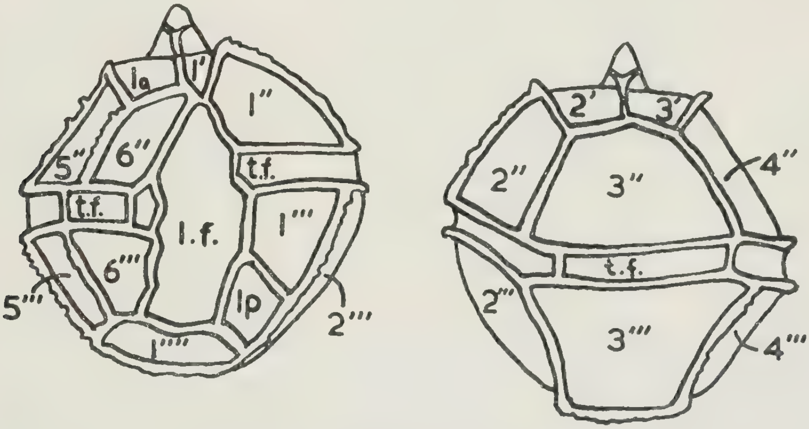
Three fossil species previously recorded also bear reticulate patterning. One, *Gonyaulax obscura* Lejeune-Carpentier, from the Cretaceous of France and Germany (1946), differs by having a polygonal theca with a very thick membrane and a very different tabulation clearly marked by high sutures. *Palaeoperidinium ventriosum* O. Wetzel, a Cretaceous dinoflagellate recorded by the German author from the Baltic region (1933) and by Deflandre from France (1936), is similar in outline, but the theca is globular and its crests bear 'thin and transparent veils'. Its tabulation, which has led Lejeune-Carpentier to suggest its attribution to the genus *Peridinium*, is quite different. Closest comparison is found in the Oxfordian *Palaeoperidinium dictyophorum* Deflandre, attributed to that genus in absence of precise knowledge of the tabulation but considered by its author probably relatable to *Gonyaulax*. This species, recorded from Villers-sur-Mer, France, differs from *G. areolata* in the shape of its apical horn, broad and very blunt, in the absence of raised crests, and in the greater breadth of the longitudinal furrow.

Gonyaulax sp.

Plate 13, fig. 15; text-fig. 6

Specimen. SC2/28/9, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions.* Overall length 47 μ, length of horn 5 μ; overall breadth 45 μ, width of transverse furrow *c.* 5 μ.

Description. Theca globular to polyhedral, yellowish in colour and lacking any pronounced granulation, divided into plates by raised sutures. Apex occupied by strong tapering horn, appearing to comprise three apical plates. Anterior intercalary plate present, situated on right-hand side of posterior extension of plate 1′; six pre-equatorial plates present, plate 6″ reduced. Transverse furrow extends around theca in a laevo-rotatory spiral such that its two ends differ in antero-posterior position by the furrow's width. The more posterior of its two ends separated from longitudinal furrow by a small pentagonal plate. Longitudinal furrow very broad extending to antapex. Six post-equatorial plates, the first being reduced to accommodate a posterior intercalary plate. A single polygonal plate occupies the antapex. Character of the raised sutures obscure in the single specimen found; the suture between plates 5″ and 6″ appears high and with a denticulate edge, resembling sutures of *Gonyaulax jurassica*, but other sutures appear low, with isolated simple spines.



TEXT-FIG. 6. Tabulation of *Gonyaulax sp.* Left: in ventral view. Right: in dorsal view. Holotype SC2/28/9. ×1,000.

Remarks. In its shape, the character of its apical horn, and its tabulation this specimen is distinctive. In view of the obscure nature of its sutural crests and the fact that only one specimen of it has been found (from the lowest Oxford Clay horizon) it was thought inadvisable to erect a new species until further specimens become available.

? Family DEFLANDREIDAE

Genus SCRINIODINIUM Klement 1957

Scriniodinium crystallinum (Deflandre 1938) Klement 1957

Plate 14, figs. 9–12

Remarks. This species has been recorded from the Oxfordian of France (Deflandre 1938), from the Upper Jurassic of Germany (Klement 1957), and from the Upper Jurassic of Western Australia and Papua (Cookson and Eisenack 1958).

Observed distribution: Oxford Clay, lowest 14, 25-foot 3, 100-foot 33; absent from the Kellaways Rock. Specimen CB81/10/8 exhibits typical dimensions: length of cyst 78 μ, breadth 75 μ, length of theca 62 μ, breadth 55 μ, transverse furrow *c.* 5 μ wide. The largest seen was specimen SC2/15/30, with a cyst 95 μ long and 80 μ broad, and a theca 65 μ long and 65 μ broad. Specimen CB81/22/7 shows a greater proportionate breadth: cyst 78 μ long and 81 μ broad, theca 63 μ long and 63 μ broad. All these dimensions are within the range recorded by Deflandre (cyst 65–92 μ × 65–85 μ). Some specimens have the appearance of possessing a longitudinal furrow (notably CB81/7/16 and SC2/11/18), but this may be due merely to folding of the thecal membrane.

Scriniodinium galeritum (Deflandre 1938) comb. nov.

Plate 14, fig. 6

1938 ? *Gymnodinium galeritum* Deflandre, p. 167, pl. v, figs. 7–9, pl. vi, fig. 1.

Diagnosis. Epitheca in the form of a truncated cone, separated by a narrow transverse furrow from the rounded hypotheca. Enclosing cyst similar in shape but having a protuberant portion which appears to cap the apex.

Remarks. One well-preserved and two broken specimens from the 100-foot Oxford Clay horizon have been attributed to this species, previously recorded only from the Oxfordian of Villers-sur-Mer, France. Specimen CB81/23/17 (figured) has an overall length 118 μ and overall breadth 103 μ, dimensions considerably greater than those recorded by Deflandre (length 78 to 87 μ, breadth 60 to 65 μ). The theca gives suggestion of a broad longitudinal furrow: however, this may be due entirely to folding of the thecal membrane. In view of its possession of an enclosing cyst this species has been

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EXPLANATION OF PLATE 14

Microplankton from the Oxford Clay of Yorkshire. All figures are × 500.

Figs. 1–2. *Gonyaulax cladophora* Deflandre. 1, CB81/10/5, in dorsal view. 2, SC2/36/4, in ventral view.

Figs. 3–5. *Baltisphaeridium pilosum* (Ehrenberg) comb. nov. 3, CB81/24/2. 4, CB81/15/7. 5, SC2/35/9.

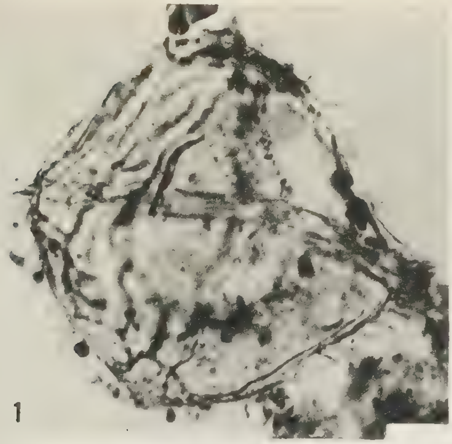
Fig. 6. *Scriniodinium galeritum* (Deflandre) comb. nov. CB81/23/17.

Fig. 7. *Polystephanosphaera calathus* sp. nov., SC2/11/9, holotype.

Fig. 8. *Baltisphaeridium pilosum* (Ehrenberg) var. *longispinosum* nov., SC2/4/10, holotype.

Figs. 9–12. *Scriniodinium crystallinum* (Deflandre). 9, SC2/15/30. 10, CB81/18/7. 11, CB81/10/8. 12, CB81/22/7.

Fig. 13. *Baltisphaeridium* cf. *fimbriatum* (White). CB81/18/17.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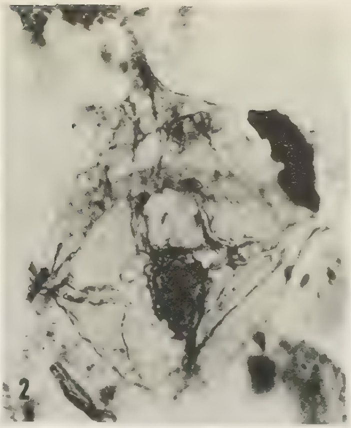
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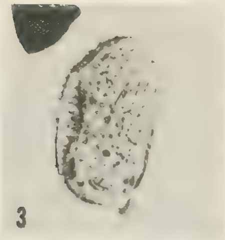
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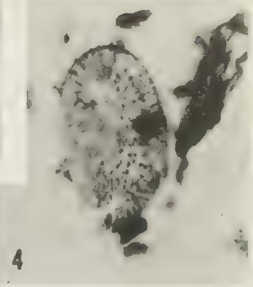
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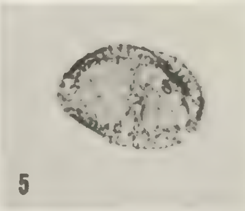
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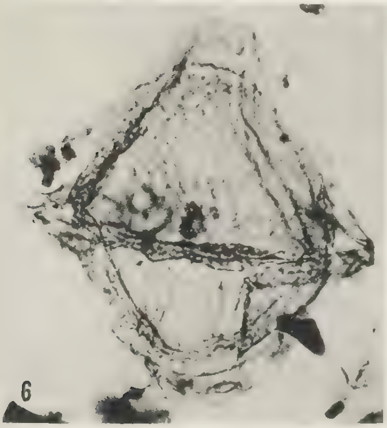
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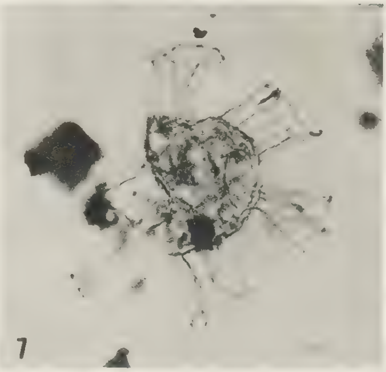
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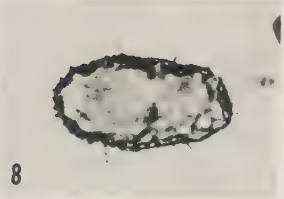
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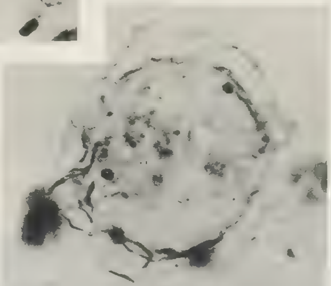
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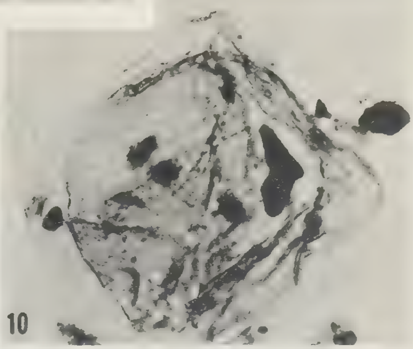
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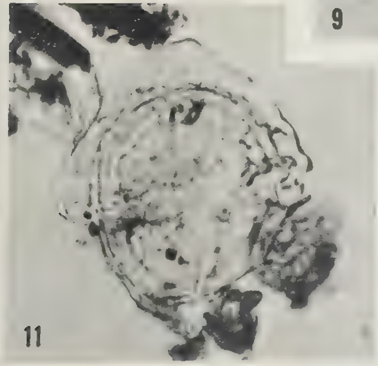
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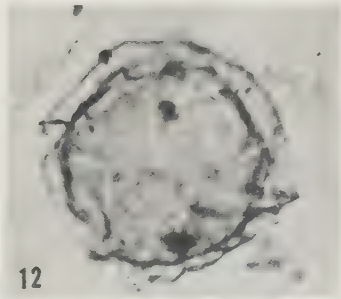
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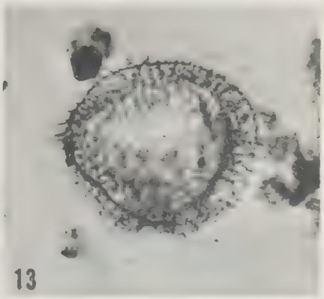
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SARJEANT, Jurassic microplankton

removed from the genus *Gymnodium* Stein in which Deflandre tentatively put it, and attributed to the newer genus *Scriniodinium* Klement.

Family PAREODINIDAE

Genus PAREODINIA Deflandre

Pareodinia ceratophora Deflandre 1947

Plate 13, fig. 16

Remarks. The typical specimens of this species have a horn tapering to a point. Twelve specimens seen, all from the 100-foot Oxford Clay horizon, show this character: all have a coarsely granular pale-yellowish membrane. Specimen CB81/6/4 is among the best preserved: it has a length of 75 μ, of which the horn comprises 15 μ, and a breadth of *c.* 40 μ. The other specimens seen are of similar dimensions, falling well within the range of dimensions (length 65–78 μ) recorded by Deflandre from specimens from the Callovian of the Baltic region and the Bajocian of France.

Pareodinia ceratophora Deflandre var. *pachyceras* Sarjeant 1959

Plate 13, fig. 17

Remarks. This variety was originally described from the Cornbrash of Cayton Bay. Four specimens attributable to it were found, all from the lowest Oxford Clay horizon. Specimen SC2/33/25 is typical: overall length 59 μ, of which the horn comprises *c.* 12 μ, and breadth 34 μ, dimensions within the range exhibited by the Cornbrash specimens. No representatives of the genus *Pareodinia* were noted from the Kellaways Rock.

Order HYSTRICHOSPHAERIDIA

Family HYSTRICHOSPHAERIDAE

Genus HYSTRICHOSPHAERIDIUM Deflandre 1937 emend. Eisenack 1958

Hystrichosphaeridium salpingophorum (Deflandre 1935)

Plate 15, fig. 7

Remarks. A long-ranging species, described already from the Oxfordian (Deflandre 1938: France), the Lower to Upper Cretaceous (Deflandre 1935 and 1937 and others from France, Lejeune-Carpentier 1940 from Belgium, and Deflandre and Cookson 1955 from Papua), from the Eocene (Pastiels 1948: Belgium), and from the Oligocene (Gocht 1952: Germany).

Observed distribution: Oxford Clay, lowest 8, 25-foot 3. The illustrated specimen (SC2/28/6) has an overall diameter 100 μ, shell diameter 50 μ, and processes around 25 μ long, dimensions closely comparable with those of the French Oxfordian specimens.

Hystrichosphaeridium cf. *truncigerum* Deflandre 1937

Plate 15, fig. 6

Specimen. CB81/12/20, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Overall long diameter 68 μ, overall short diameter 56 μ, long diameter of shell 58 μ, short diameter of shell 48 μ, spines *c.* 5 μ long, tubes *c.* 7·5 μ long

Description. Shell oval, yellowish, with thin walls bearing a very faint granulation. Processes of two kinds: *a*, Hollow conical spines, closed, thickening (slightly) at the tip to form a knob. *b*, Short, broad, roughly parallel-sided tubes not widened at their extremity, bearing very faint striations. Slightly longer than the spines.

Processes quite widely separated and without apparent arrangement. On a complete specimen it is estimated that there would be thirty to forty processes: of these about one-third would be tubes.

Remarks. Only one damaged specimen was seen of this interesting microfossil. In the general appearance of its processes it accords well with Deflandre's *Hystrichosphaeridium truncigerum* from the Cretaceous of France (1937). In four respects it differs from this species, however; in the oval, rather than spherical, shape of the shell, in the somewhat knobbed tips of some spines, in the absence of denticulations on the outer margins of the tubes, and in the smaller relative length of the processes (one-sixth to one-quarter short diameter, as against nearly half diameter). It is thus probable that this single specimen will be attributed to a new species when further specimens of similar type are found.

Genus BALTISPHAERIDIUM Eisenack 1958

Baltisphaeridium stimuliferum (Deflandre 1938) comb. nov.

Plate 15, fig. 5; text-fig. 8*g*

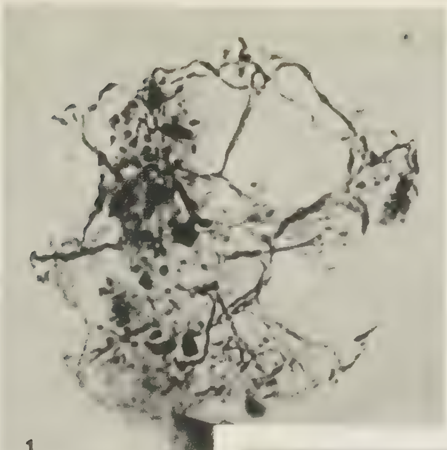
1938 *Hystrichosphaeridium stimuliferum* Deflandre, p. 192, pl. x, fig. 10.

Diagnosis. A species of *Baltisphaeridium* having a globular shell bearing a small number (about fifteen) of simple spines, generally curved, in length of the order of the diameter of the shell. The spines are inserted in such fashion that there is no mark at their base and the wall of the shell appears continuous with each spine.

EXPLANATION OF PLATE 15

Microplankton from the Oxford Clay of Yorkshire. All figures are ×500.

Fig. 1. *Cannosphaeropsis aemula* (Deflandre), CB81/7/15.
Fig. 2. *Micrhystridium stellatum* Deflandre, CB81/14/20.
Fig. 3. ? *Micrhystridium sp.*, CB81/17/22.
Fig. 4. *Cannosphaeropsis caulleryi* (Deflandre), CB56/8/4.
Fig. 5. *Baltisphaeridium stimuliferum* (Deflandre) comb. nov., SC2/10/17.
Fig. 6. *Hystrichosphaeridium* cf. *truncigerum* Deflandre, CB81/12/20.
Fig. 7. *Hystrichosphaeridium salpingophorum* Deflandre, SC2/28/6.
Fig. 8. *Baltisphaeridium ehrenbergi* (Deflandre) var. *brevispinosum* nov., SC2/34/8, holotype.
Fig. 9. *Cymatiosphaera teichophera* sp. nov., CB81/19/17, holotype.
Fig. 10. ? *Cymatiosphaera* sp. indet., CB56/12/18.
Fig. 11. *Stephanelytron redcliffense* gen. et sp. nov., CB81/26/6, holotype.
Figs. 12–13. *Stephanelytron scarburghense* gen. et sp. nov. Two views of the holotype, SC2/31/2 (obliquely positioned) at different focal planes.
Fig. 14. *Wanaea fimbriata* sp. nov., CB56/8/15, holotype.
Fig. 15. *Netrelytron stegastum* gen. et sp. nov., CB81/16/10, holotype.
FIG. 16. *Stephanelytron caytonense* gen. et sp. nov., CB56/14/1, holotype.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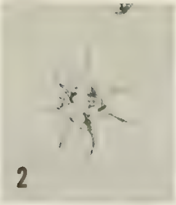
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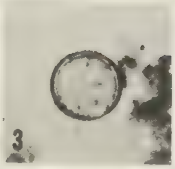
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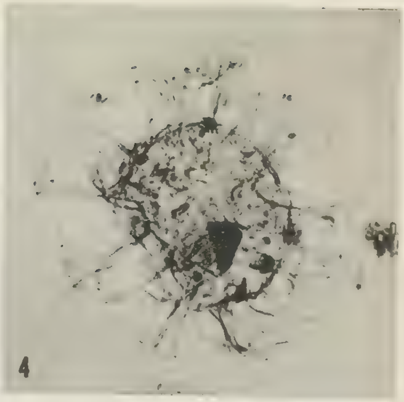
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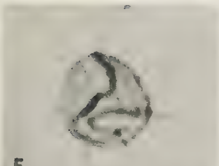
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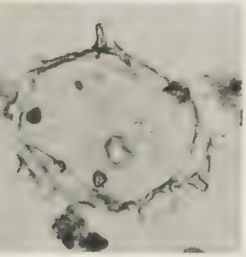
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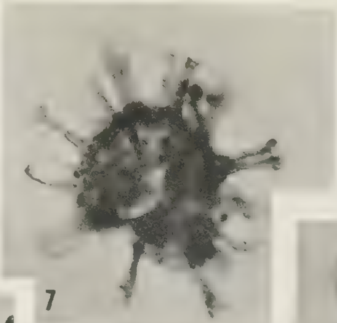
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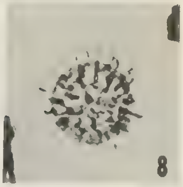
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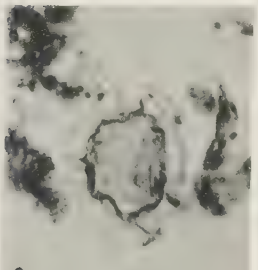
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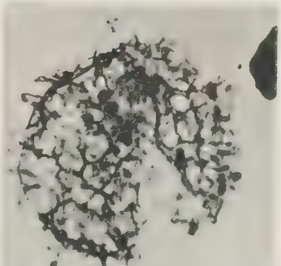
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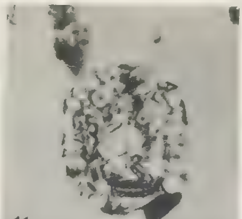
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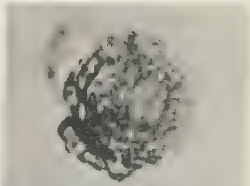
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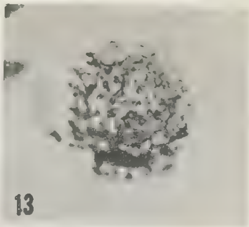
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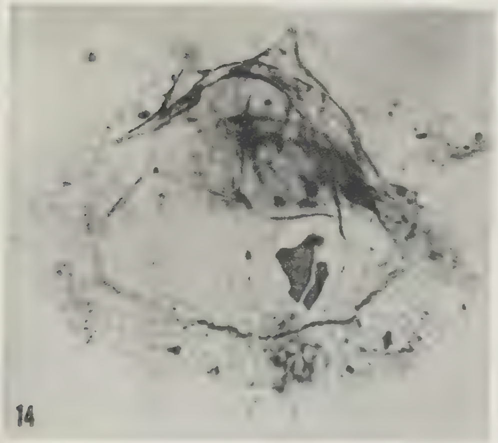
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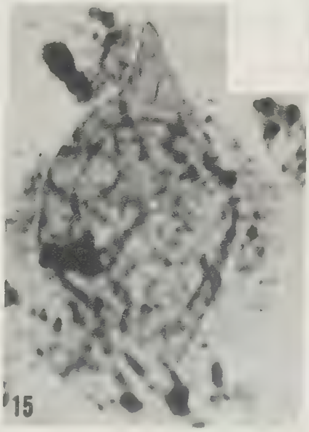
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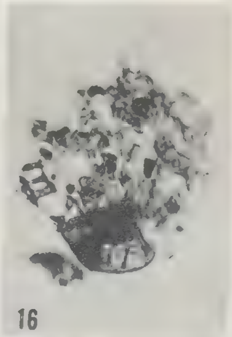
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Remarks. This species has been described from the Bajocian and Bathonian (Deflandre 1947; Valensi 1953) and Oxfordian (1938) of France. Observed distribution: Oxford Clay, lowest 6, 25-foot 3, 100-foot 2.

The spines were originally thought by the author to be solid; after repeated examination, however, it was established that they are hollow but closed at the tips. The species has therefore been transferred to Eisenack's genus *Baltisphaeridium.*

Specimen SC2/10/17 (figured) has an overall diameter of 47 μ and shell diameter of 26·5 μ, with spines *c.* 12 μ long. This spine length is proportionately shorter than that of typical forms, and the greatest length observed was only three-quarters the diameter. However, Valensi has already included specimens of similar relative dimensions (shell 20 μ, spines 10–15 μ long) within the species (1953).

Baltisphaeridium pilosum (Ehrenberg 1843) comb. nov.

Plate 14, figs. 3–5

1843 *Xanthidium pilosum* Ehrenberg, pp. 61–63.
1854 *Xanthidium pilosum* Ehrenberg, pl. 37, fig. viii, no. 4.
1904 *Ovum hispidum* (*Xanthidium*) *pilosum* (Ehr.) Lohmann, Ergebnisse der Planktonexpedition der Humboldt-Stiftung, pp. 21–25.
1933 *Hystrichosphaera pilosa* (Ehr.) O. Wetzel, p. 43.
1937 *Hystrichosphaeridium pilosum* (Ehr.) Deflandre, p. 31.

Figured specimen CB81/15/7, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Figured specimen: overall long diameter 62 μ, short diameter 40 μ; long diameter of shell 55 μ, short diameter 33 μ, spines around 3½ μ long. Relatively complete specimens from which both major dimensions could be taken were few: the range of overall long diameters was 40–60 μ. Ehrenberg's holotype (53 μ) falls within this range.

Diagnosis. A species of *Baltisphaeridium* having a shell ellipsoidal to oval in shape, frequently broken at one termination. Shell wall very thin. Processes short (between one-quarter and one-eighth of short diameter in length), slender, pointed, and hollow (connecting directly to the interior of the shell); very numerous.

Description. Shell yellowish; all specimens seen in some degree broken, one extremity usually being missing, although quite frequently also the shell is split longitudinally. Processes very densely set, the spacing none the less being such as to allow each to be seen throughout its length; 150–200 present around the periphery in relatively complete specimens.

Remarks. This hystrichosphere was listed by Ehrenberg from the Corallian of Kraków, Poland (1843); in 1854 a figure of it was included in his massive *Mikrogeologie.* All subsequent generic reattributions of this species were on taxonomic grounds only: the form *nanum* of this species described by O. Wetzel from the Cretaceous (1933), distinguished by small size (shell diameter less than 16 μ) and a frequently spherical shape, is perhaps better attributed to the genus *Micrhystridium.* Ehrenberg gave no full diagnosis of this species and his holotype appears to be lost; however, the Yorkshire specimens correspond exactly with his figure. Observed distribution: Oxford Clay, lowest 33, 25-foot 9, 100-foot 43. All seen are broken in some degree (see above); this may well indicate that eggs or cysts of microplankton are being dealt with here, a suggestion already made by O. Wetzel.

Baltisphaeridium pilosum (Ehrenberg 1843) var. *longispinosum* nov.

Plate 14, fig. 8

Holotype. SC2/4/10, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions.* Holotype: overall long diameter 70 μ, short diameter 47 μ; long diameter of shell 51 μ, short diameter 28 μ; spines around 12 μ long.

Diagnosis. A variety of *Baltisphaeridium pilosum* having spines between one-quarter and one-third the short diameter of the shell in length.

Remarks. The single specimen dealt with here is in appearance quite distinct from all others seen. The shell shows no signs of breakage; its spines are more than three times longer than those of the figured specimen of *B. pilosum* and considerably in excess of the range of relative lengths exhibited. This distinctive specimen from the lowest Oxford Clay may well be a representative of a species distinct from *B. pilosum*. However, in the absence of further specimens the making of such a major distinction was not thought justifiable.

Baltisphaeridium cf. *fimbriatum* (White 1842)

Plate 14, fig. 13

Figured specimen. CB81/18/17, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Figured specimen: overall diameter 70 μ, diameter of shell 58 μ, spines *c.* 6 μ in length. The range exhibited is from 50 to 75 μ overall diameter.

Description. Shell yellowish-brown, spherical to oval in shape, very frequently damaged. Processes very numerous, typically 100–150 observable around the periphery: short, sometimes simple but more frequently forked or capitate, their length typically around 10 per cent. of the shell diameter.

Remarks. Hystrichospheres of this type proved frequent. Observed distribution: Kellaways Rock 3, Oxford Clay, lowest 18, 25-foot 5, 100-foot 22. However, despite examination at magnifications of ×2,000, whether or not the spines are hollow could not be decisively determined and their attribution to this genus remains doubtful.

The closest comparison is found in *Baltisphaeridium fimbriatum* (White), originally described from Cretaceous flints from England (1842) and subsequently redescribed by Deflandre and Cookson from the Lower Cretaceous of New South Wales (1955). This species has spines of comparable length and with capitate or furcate apices; it differs in the total absence of simple spines and the somewhat longer spine branches. Another described character of this species is the constancy of the length of the spines, giving almost the aspect of an outer shell: two of the Kellaways Rock specimens have somewhat this appearance, but the Oxford Clay specimens do not give it, their spines being slightly variable in length. It is likely that these Upper Jurassic specimens are not genetically related to the Cretaceous species, but the morphological distinctions listed above are not adequate to justify nomenclatural separation. In dimensions, the Jurassic assemblage is closer to White's specimens (overall diameter 51–77 μ) than to the Australian specimens (31–46 μ).

Baltisphaeridium ehrenbergi (Deflandre 1947) comb. nov.

1938 *Hystrichosphaeridium* cf. *hirsutum* (Ehrenberg) Deflandre, pl. x, fig. 9.
1947 *Hystrichosphaeridium ehrenbergi* Deflandre, fig. 1, no. 5.
1955 *Hystrichosphaeridium ehrenbergi* Valensi, p. 587, pl. iii, fig. 1.

Diagnosis. Shell globular, bearing simple processes, straight or slightly curving, about one-third the shell diameter in length. Points of insertion of processes equidistant.

Remarks. On the basis of Valensi's description of the processes this species is transferred to *Baltisphaeridium* on taxonomic grounds.

Baltisphaeridium ehrenbergi (Deflandre) var. *brevispinosum* nov.

Plate 15, fig. 8; text-fig. 8*a*

Holotype. SC2/34/8, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions*. Holotype: overall diameter 34 μ, shell diameter 25 μ, length of spines 5 μ.

Diagnosis. A variety of *Baltisphaeridium ehrenbergi* having shorter spines, one-fifth to one-quarter of the shell diameter in length.

Description. Shell yellowish-brown in colour, not granulous. Spines regularly spaced, about 3·5 μ apart in the holotype. Shell wall thin.

Remarks. A single specimen from the lowest Oxford Clay, excellently preserved, was found to correspond with Deflandre's species *B. ehrenbergi*, from the Oxfordian of Villers-sur-Mer, France, in the character and regularity of spacing of its spines. Since the sole difference is in the length of its spines, it has been created a new variety of this species.

Genus CANNOSPHAEROPSIS O. Wetzel 1933 emend. Deflandre 1947

Cannosphaeropsis caulleryi (Deflandre 1938)

Plate 13, fig. 8 and Plate 15, fig. 4

Remarks. This species was originally recorded from the Oxfordian of Villers-sur-Mer, France (1938), and subsequently from the Kimeridgian of Dorset, England (Downie 1957), the Neocomian of Germany (Gocht 1959), and the Eocene of Australia (Deflandre and Cookson 1955). Observed distribution: Kellaways Rock 1, Oxford Clay, lowest, 28, 25-foot 22, 100-foot 15.

There was considerable variation in size, overall diameter varying from 55 to 120 μ; the figured specimen (CB56/8/4) has average dimensions, with an overall diameter of 92 μ and shell diameter 50 μ. This range is not exceptional: the French specimens range from about 65 to 85 μ and the Australian from 67 to 115 μ.

Cannosphaeropsis aemula (Deflandre 1938)

Plate 15, fig. 1

Remarks. This species was originally described from the Oxfordian of Villers-sur-Mer, France (1938), and subsequently from the Upper Jurassic of Papua and Western Australia (Cookson and Eisenack 1958). It was found only in the 100-foot Oxford Clay horizon (9). The figured specimen (CB81/7/15) has average dimensions (overall diameter 106 μ, shell diameter 52 μ), the range being from 95 to 120 μ overall diameter; this is somewhat larger than that exhibited by the French specimens (60 to 100 μ).

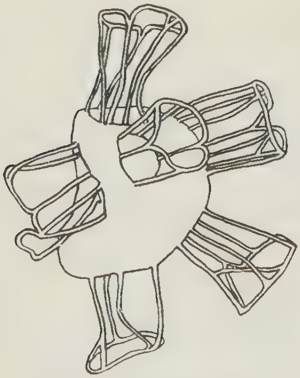
Genus POLYSTEPHANOSPHAERA Sarjeant 1960

Polystephanosphaera calathus sp. nov.

Plate 14, fig. 7; text-fig. 7

Holotype. SC2/11/9, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions.* Holotype: overall diameter 88 μ, shell diameter 45 μ, length of process clusters *c.* 22 μ. Paratype (CB56/8/24): overall diameter 90 μ, shell diameter 45 μ, length of process clusters *c.* 23 μ.

Diagnosis. A species of *Polystephanosphaera* in which the processes are solid and are arranged in circles and connected together by trabeculae in the form of a ring, each cluster of processes thus forming an open-walled and open-ended tube. It is estimated that on a complete specimen there would be twelve to sixteen such tubes, each ring trabecula borne by five to ten processes.



TEXT-FIG. 7. *Polystephanosphaera calathus* sp. nov., showing the form of the groups of processes. Holotype SC2/11/9. ×600.

Description. The trabecula linking each group of processes appears to arise from the bifurcation of one process in Y-shaped fashion, the tips of the two arms of the Y being extended parallel to the shell surface and meeting the extremities of the other processes of the group almost at right angles. Shell membrane brownish-yellow in colour, processes pale-yellowish.

Remarks. Only two specimens found of this very characteristic microfossil, one each from the lowest and 25-foot horizons.

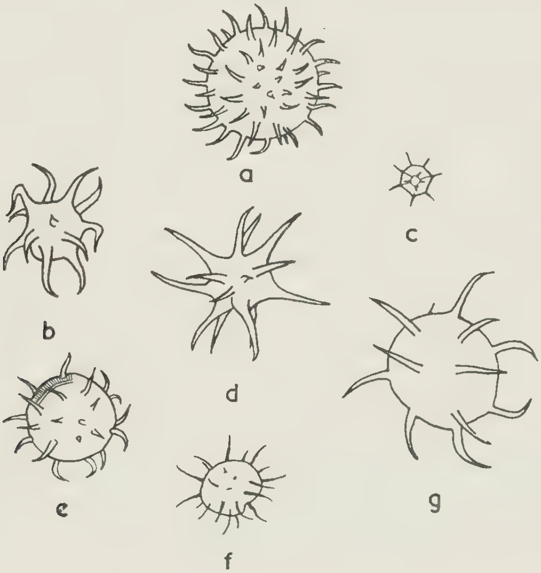
The processes of *Cannosphaeropsis caulleryi* are similar in basic type but are not arranged in circles. Those of *P. urnaformis* from the Oligocene of Australia (Cookson 1953) differ in that this latter species has processes whose bases coalesce, giving the impression rather of a perforated tubular process than of a group of linked processes. It might be suggested purely on morphological grounds that *P. calathus* represents an intermediate stage in evolutionary development from *C. caulleryi* to *P. urnaformis*. However, the geographic and chronologic separation is immense and an actual genetic relationship must be at present considered improbable.

Genus MICRHYSTRIDIUM Deflandre 1936

Micrhystridium inconspicuum (Deflandre 1935)

Plate 13, fig. 5; text-fig. 8*f*

Remarks. A long-ranging species, previously recorded from the Middle Jurassic of France (Valensi 1953), the Cornbrash of England (Sarjeant 1959), and the Cretaceous of France (Deflandre 1935). Observed distribution: Kellaways Rock 3, Oxford Clay, lowest 2, 25-foot 8, 100-foot 9. Specimen CB81/14/12 (illustrated) has an overall diameter 25 μ and shell diameter 12 μ, spines being around 7 μ long. This is rather larger than specified by Deflandre: however, a range of shell diameters from 15 μ down to 8 μ was observed and in all other characters these specimens agree with Deflandre's definition of the species.



TEXT-FIG. 8. Smaller hystrichospheres from the Oxford Clay. *a*, *Baltisphaeridium ehrenbergi* (Defl.) var. *brevispinosum* nov. (Holotype SC2/34/8); *b*, *Micrhystridium recurvatum* forma *reducta* Valensi (CB81/26/10); *c*, *M.* cf. *mendax* Deflandre (SC2/30/11); *d*, *M. stellatum* Deflandre (CB81/14/20). *e*, ?*M. sp.*, showing the two layers of the shell wall (CB81/17/22); *f*, *M. inconspicuum* (Deflandre CB81/14/12); *g*, *Baltisphaeridium stimuliferum* (Deflandre) (SC2/10/17). ×600.

Micrhystridium fragile Deflandre 1947

Plate 13, figs. 3–4

Remarks. Two specimens found in the Kellaways Rock, but this species is absent from the Oxford Clay horizons studied. It has previously been described from the Bajocian and Bathonian of France (Deflandre 1947, Valensi 1953) and from the Cornbrash of England (Sarjeant 1959).

Specimen SC33/17/5 is the better preserved; its dimensions are overall diameter 52 μ, shell diameter 24 μ. These dimensions are considerably larger than those recorded by Deflandre (overall diameter 12 to 14 μ); however, Valensi noted a considerable range of dimensions, the diameter of the shell alone in one case attaining 40 μ, so that the Kellaways specimens are not exceptional.

Micrhystridium stellatum Deflandre 1942

Plate 15, fig. 2; text-fig. 8*d*

Remarks. This species was originally recorded from the Silurian (1942). Morphologically similar forms, probably not genetically related, have been recorded from the Bajocian of France (Valensi 1953) and the Cornbrash of Yorkshire (Sarjeant 1959). Their significance has already been discussed (1959). No representatives were seen from the Kellaways Rock, but the species was present at all three horizons of the Oxford Clay (lowest 16, 25-foot 7, 100-foot 15). The figured specimen (CB81/14/20) exhibited typical dimensions: shell diameter 14 μ, spines around 12·5 μ in length; range of shell diameters from 10 to 25 μ.

Micrhystridium recurvatum forma *reducta* Valensi 1953

Text-fig. 8*b*

Remarks. This species and form were originally described from the Bathonian of France. Specimens corresponding to the diagnosis of this form are present in low numbers in all horizons studied (Kellaways Rock 3, Oxford Clay, lowest 3, 25-foot 1, 100-foot 3). Little variation in dimensions was exhibited, the figured specimen (CB81/26/10) being typical with overall diameter *c.* 35 μ, shell diameter 12·5 μ. Comparable dimensions are recorded by Valensi: shell diameter 11 to 15 μ, overall diameter 20–30 μ. Despite the considerable morphological similarities with *Micrhystridium stellatum* Deflandre, there was no suggestion of intergradation between the two species in the assemblages examined.

Micrhystridium cf. *mendax* Deflandre 1945

Text-fig. 8*c*

Figured specimen. SC2/30/11, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions.* Figured specimen: shell 11 μ in cross measurement, spines 1·5 μ long. The two other specimens seen were similar in dimension.

Description. Shell polygonal, pale-yellowish in colour, composed of a series of more or less flat fields whose intersections form low ridges. Short simple spines arise at the junctions of ridges; they are hollow and connected directly to the interior.

Remarks. One specimen showing these characters was found in the lowest and two in the 25-foot Oxford Clay horizons. The closest comparison is found in *Micrhystridium mendax* Deflandre, from the Silurian of the Montagne Noire, France. This has the characters listed in the description: its spines are, however, proportionately shorter, only one-seventh to one-eighth the cross measurement as against one-fifth; the shell is also somewhat smaller, the Silurian specimens measuring 14 to 16 μ. These differences are by no means sufficient to justify the setting up of a new species, but the tremendous chronologic separation makes any genetic relationship unlikely.

? *Micrhystridium sp.*

Plate 15, fig. 3; text-fig. 8*e*

Figured specimen. CB81/17/22, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Figured specimen: shell diameter 21 μ with walls *c.* 2 μ thick. Spines 7 μ long. The other specimens seen have closely similar dimensions.

Description. Shell exactly spherical, brownish-yellow, composed of two layers, a thick outer layer (striate) and a thin inner layer (not striate). Spines short (*c.* one-third to one-quarter diameter), simple, usually curving, solid and embedded in the outer layer of the shell wall.

Remarks. The forms included here, in their possession of a two-layered shell wall, differ from all other Mesozoic hystrichospheres described to date, and resemble certain Palaeozoic forms (cf. Sannemann 1958). Their attribution to the Order Hystrichosphaeridia is not necessarily correct; many pollen possess a two-layered body wall and the differentiation of the simpler pollen grains from hystrichospheres at this order of size is by no means easy. For this reason they have been only tentatively allotted to this order and genus.

Microfossils of this type occur at all three Oxford Clay horizons (lowest 15, 25-foot 7, 100-foot 9) but were not noted from the Kellaways Rock.

Family PTEROSPERMOPSIDAE

Genus CYMATIOSPHAERA O. Wetzel 1933 emend. Deflandre 1954

Cymatiosphaera teichophera sp. nov.

Plate 15, fig. 9; text-figs. 9*a,b*

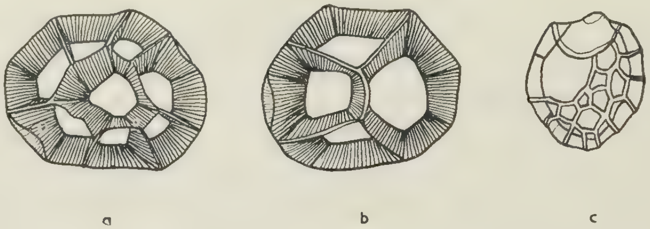
Holotype. CB81/19/17, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Holotype: overall long diameter 50 μ, overall short diameter 40 μ, crests around 9 μ high.

Diagnosis. A species of *Cymatiosphaera* having a broadly ellipsoidal shell divided into a low number (12–16) of polygonal fields. The membranes delimiting fields are high, their height equal to about one-third of the short diameter; they bear striations normal to the shell surfaces.

Description. Shell walls of moderate thickness and of brownish-yellow colour. Fields vary considerably in size; their separating membranes are thin and relatively readily crumpled, lacking supporting spines at the junctions but having a distinct outer edge on to which striations do not extend.

Remarks. A single specimen only was found of this distinctive microfossil. Four known species have crests of similar proportional height. All are very much smaller in size than *C. teichophera*, lack striations on their crests, and also differ as follows: *Cymatiosphaera eupeplos* Valensi, from the Middle Jurassic of France (1948), has membranes supported by spines at their junction. The other three comparable species have been described by Deunff from the Devonian of Canada. *C. cornifera* (1955) has fields with a short spine at their centre. *C. cubus* (1954) has a distinctly cubic outline and fewer fields. *C. prismatica* (1954) has a prismatic outline.

Thus this new species is seen to be clearly distinct from all others of this genus so far described.



TEXT-FIG. 9*a*, *b*, *Cymatiosphaera teichophera* sp. nov., showing the two opposed surfaces, with the structure and arrangement of crests; the striations are less prominent than the drawing suggests. Holotype CB81/19/17. *c*, *Membranilarnax ovulum* Deflandre (SC2/24/1). ×600.

Cymatiosphaera parva Sarjeant 1959

1959 *Cymatiosphaera parva* Sarjeant, pp. 342–3, pl. xiii, fig. 6, text-fig. 8.

Emended diagnosis. A species of *Cymatiosphaera* with a low number (*c*. 12–25) of polygonal fields demarcated by low ridges. Short slender spines arise at the junctions of the ridges.

Remarks. This species, originally described from the Cornbrash (1959), was the most abundant in the Kellaways Rock (31 specimens seen), but was not observed from the Oxford Clay. The number of plates is generally twelve to fifteen. Specimen SC33/5/15 shows characteristic dimensions—overall diameter 13 μ, shell diameter 10 μ. There was little variation in dimensions exhibited; the shell diameters of the Kellaways specimens are thus almost exactly half that of the type specimen (20 μ). The rather low plate number (12–15 as against 17–20) appears merely a function of size. The definition of a new variety on the basis of size alone seems scarcely warranted, particularly since size may be merely a reflection of age or environmental conditions. The diagnosis of the species has therefore been modified slightly to accommodate the Kellaways assemblage.

? *Cymatiosphaera* sp. indet.

Plate 15, fig. 10

Remarks. Two poorly preserved specimens from the 25-foot Oxford Clay horizon may be attributable to this genus. Their shape was probably originally spherical; the test surface is divided into very numerous polygonal fields by low membranes sustained by spines at their junctions, these spines being sometimes bifurcate. The overall diameter of the better specimen (CB56/12/18) is 65 μ, the spines being 4 μ in height. In view of their poor preservation these two specimens cannot be attributed with any certainty to this genus, particularly since certain Mesozoic pollen grains, such as *Lycopodiumsporites clavatoides* Couper (present in this material), have a similar ornament.

Genus MEMBRANILARNAX O. Wetzel 1933

Membranilarnax ovulum Deflandre 1947

Text-fig. 9*c*

Remarks. This species has been described from the Bajocian and Bathonian of France (Deflandre 1947, Valensi 1953). A single poorly preserved specimen (SC/224/1) attributable to it was found in the lowest Oxford Clay horizon; its dimensions, long diameter 30 μ, short diameter 25 μ, with crests around 4 μ high, are smaller than the range quoted by Valensi (long diameter 38–60 μ, short diameter 34–50 μ).

INCERTAE SEDIS

Genus STEPHANELYTRON gen. nov.

Type species. Stephanelytron redcliffense sp. nov.

Diagnosis. Organic shells of spherical to ovoidal shape, bearing on one face (at one end in ovoidal forms) one or more structures consisting of a circular membrane rising upwards from the shell surface and everted, surrounding a matte of short hairs or spines; this structure is henceforth termed a ‘corona’. Elsewhere the shell bears tubular processes of varied character and arrangement.

Remarks. In view of the uncertain function and character of the corona, any orientation imposed must be quite arbitrary. By analogy with other members of the marine plankton in which groups of cilia confined to one surface act as propellants it has been decided to term the surface bearing the corona or coronas the antapex, and the opposed surface the apex; it must be realized, however, that no comparison of function is implied. The presence of tubular processes makes it possible to relate this genus to the Order Hystrichosphaeridia, but the corona has no parallel in any known hystrichosphere, so that it seems best for the present that this genus should remain *incertae sedis.*

Stephanelytron redcliffense sp. nov.

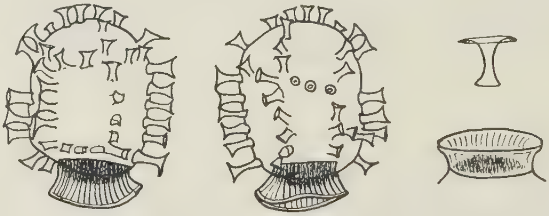
Plate 15, fig. 11; text-fig. 10

Holotype. CB81/2/66, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Holotype: overall length 50 μ, breadth 40 μ, length of shell *c.* 36 μ, breadth *c.* 30 μ; height of corona 10 μ, outer diameter *c.* 27 μ. Tubes around 5 μ in length. Two other relatively complete specimens, similar in dimensions, were seen, and in addition several broken specimens.

Diagnosis. A species of *Stephanelytron* having an oval shell, neither granular nor perforate, bearing six rows of tubular processes extending from the apex to the corona, a transverse row of tubular processes extending around the apex in a broad circle, and a further row of processes, incomplete in all specimens seen, surrounding the antapex close to the base of the corona. The processes have everted lips and their walls are not perforate. All specimens seen had a single corona, broad-based and bearing striations.

Description. The surrounding membrane of the corona seems to show a somewhat thickened lip on to which the striations do not extend. The matted fibres within seem to vary in length, with those at the centre longer than those at the fringes, but this appearance may result entirely from the curvature of the shell surface from which they arise.

Remarks. Each of the three Oxford Clay horizons studied seems characterized by a particular species of *Stephanelytron*, the genus not having been recorded from the Kellaways Rock. The representatives of this species occur only in the 100-foot horizon.



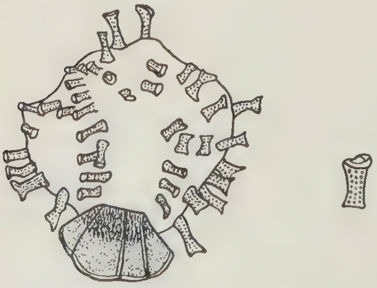
TEXT-FIG. 10. *Stephanelytron redcliffense* gen. et sp. nov. Upper and lower surfaces (×600); an individual tube (×1,250); and a sketch to illustrate the structure of the corona. Holotype CB81/26/6.

Stephanelytron caytonense sp. nov.

Plate 15, fig. 16; text-fig. 11

Holotype. CB56/14/1, 25-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* The holotype has a somewhat damaged shell: its overall dimensions, length 65 μ and breadth 60 μ, probably do not therefore reflect its true shape. The corona is 17 μ high; its outer diameter is 25 μ, its basal diameter about 14 μ. The tubes are around 8 μ in length.

Diagnosis. A species of *Stephanelytron* having a spherical to oval shell, not granular or punctate, bearing rows of tubes similar in distribution to those of *S. redcliffense* but with lips less pronouncedly everted and having about eight to ten rows of perforations aligned parallel to the length of the tube and quite closely spaced. The corona has a relatively small base and flares out widely; its membrane is somewhat folded, with a coarsely granular surface and a distinct outer lip devoid of granulation.



TEXT-FIG. 11. *Stephanelytron caytonensis* sp. nov. (×600) and an isolated tube (×1,00). Holotype CB56/14/1.

Remarks. The single specimen found of this species was the only representative of the genus noted at this horizon. However, its perforate tubes and the character of its corona afford a ready distinction from all other specimens of the genus and warrant specific status.

Stephanelytron scarburghense sp. nov.

Plate 15, figs. 12–13

Holotype. SC2/31/2, lowest Oxford Clay, Scarborough Castle cliff. *Dimensions*. Holotype: overall length 41 μ, overall breadth 30 μ (oblique view). Specimen SC2/31/12, seen in lateral view, gives more satisfactory dimensions (overall length 45 μ, breadth 40 μ, corona 12 μ high and 28 μ in outer diameter, tubes about 5 μ in length) but was unfortunately damaged. These dimensions appear typical.

Diagnosis. A species of *Stephanelytron* having a spherical to oval shell, not granular or punctate, bearing tubes similar in character and distribution to those of *S. redcliffense* but with in addition further tubes of similar character distributed in an irregular scatter within the fields delimited by these tube rows. The everted lips of the tubes in the rows overlap to some extent, giving an appearance of linkage. The corona or coronas have a surrounding membrane striated in similar fashion to that of *S. redcliffense*: however, the membrane slopes regularly outwards instead of having a distinctly everted lip.

Description. Whereas all other specimens seen of this genus have a single large corona, as does the type of *S. scarburghense*, one specimen seen (SC2/33/6) has two smaller coronas, situated together on the antapical surface. In the character of these coronas and in the type and distribution of tubes this specimen corresponds to *S. scarburghense* and it has therefore been attributed to this species, the drawing of a varietal distinction not being considered warranted in view of the absence of knowledge of the character and functions of the corona.

Remarks. This species, typical of the lowest Oxford Clay, is proportionately more abundant than the species of *Stephanelytron* of the higher horizons. Broken specimens are relatively numerous, an estimated thirty to fifty being seen, but only five relatively complete specimens were noted. The character of the corona and tubes suggests a closer relation to *S. redcliffense* than to *S. caytonense*, so that no evolutionary sequence can be postulated satisfactorily.

Genus ANTROSPHAERA gen. nov.

Type species. *Antrosphaera calloviensis* sp. nov.

Diagnosis. Organic shells of spherical shape, hollow, without processes, patterned with depressions of varied shape, size, and arrangement.

Remarks. The extreme simplicity in form of the representatives of this genus makes their attribution to any group uncertain. In the organic nature of the test there is a resemblance to both spores and pollen and to microplankton. However, there are no traces of a trilete or monolete mark; moreover, some specimens (including the type of *A. calloviensis*) were seen to contain irregular greenish bodies considered probably chloroplasts, and if these were indeed chloroplasts then these organisms could not be pollen.

The absence of any trace of tabulation or of traces of a transverse furrow makes a relationship with the Order Dinoflagellata unlikely. The absence of processes is a distinction from the majority of genera and species of the Order Hystrichosphaeridia: the genus *Leiosphaeridia* comprises simple, spherical to ovoidal bodies without processes or ornamentation (other than granules), but comparison with specimens of that genus suggested that the cell wall of *Antrosphaera* was composed of a quite different substance. Nevertheless, the possibility of a relationship with *Leiosphaeridia* remains. Until more evidence of relationship becomes available, therefore, this genus must remain *incertae sedis.*

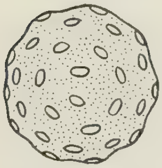
Antrosphaera calloviensis sp. nov.

Plate 13, fig. 7; text-fig. 12

Holotype. SC33/5/16. Kellaways Rock, Scarborough Castle cliff. *Dimensions.* Holotype: diameter 14 μ; the six other specimens seen were of comparable dimensions.

Diagnosis. A species of *Antrosphaera* of small size, having a granular shell surface ornamented with small ovoid depressions, regularly spaced, in arrangement as shown on the figure; about thirty such depressions appear present on either surface.

Description. Shell moderately thick, greenish in colour; outline undulose, there being some indication that the depressions are situated in the crests of slight bulges in the shell surface. Focusing indicated that the holes in the surface become smaller with depth and appear to close; they are thus considered depressions and not perforations. The type specimen contains a greenish body with a somewhat irregular surface; this was thought probably a chloroplast (discussed earlier).



TEXT-FIG. 12. *Antrosphaera calloviensis* gen. et sp. nov. ×1,425. Holotype SC33/5/16.

Remarks. Representatives of this species were found only in the Kellaways Rock assemblage. In view of its extremely small size this organism readily escapes notice; it may well be considerably more abundant at this horizon than the numbers recorded would suggest.

Genus WANAEA Cookson and Eisenack 1958

Wanaea fimbriata sp. nov.

Plate 15, fig. 14; text-fig. 13

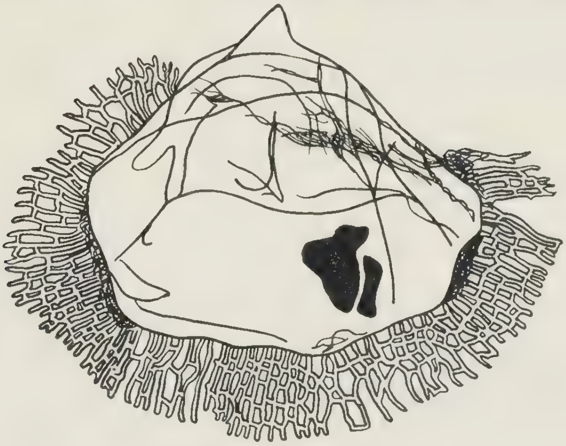
Holotype. CB56/8/15, 25-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Holotype: height of shell *c.* 65 μ, diameter of base 100 μ, fringe up to 20 μ broad. The other specimens seen vary little from these dimensions.

Diagnosis. A species of *Wanaea* with a shell broadly cone-shaped, narrowing to a short, rounded apex. The edge is ornamented for four-fifths of its length by a fringe, relatively broad but narrowing towards the gap; this fringe is in the form of a small-meshed network of irregular structure, its edges free.

Description. Fringe meshwork extremely variable in character; in some cases two adjacent processes anastomose only twice in their length, in others, they do so four times. Mesh fragile and frequently torn; it is not rigid, its surface frequently being undulose.

Remarks. Three species of this genus have so far been erected, *W. spectabilis* (Deflandre and Cookson), *W. digitata* Cookson and Eisenack, and *W. clathrata* Cookson and Eisenack. On the basis of time sequence Cookson and Eisenack have suggested that these represent an evolutionary series with *W. spectabilis* the simplest and *W. clathrata* the most highly developed (1958). All are from successive horizons in the Upper Jurassic of Australia and Papua.

Wanaea fimbriata occurs in all three Oxford Clay horizons examined (lowest 7, 25-foot 1, 100-foot 3) but was not recorded from the Kellaways Rock. In the form of the shell it resembles *W. digitata* and *W. spectabilis* and differs from *W. clathrata*; its fringe on the other hand shows closest similarity with that of *W. clathrata* but differs in that it lacks an outer edge. On morphological considerations alone an evolutionary position might be tentatively assigned after *W. digitata* and possibly before *W. clathrata*; but without more precise knowledge of the comparative ages of the Australasian horizons in relation to the Oxford Clay this remains no more than a possibility.



TEXT-FIG. 13. *Wanaea fimbriata* sp. nov. Holotype CB56/8/15. ×600.

Genus NETRELYTRON gen. nov.

Type species. Netrelytron stegastum sp. nov.

Diagnosis. Micro-organisms formed of a spherical, ovoidal, or ellipsoidal central body enclosed in a spindle-shaped outer membrane.

Remarks. Four existing genera possess a central body surrounded by an outer membrane. The new genus differs from *Pterocystidiopsis* Deflandre in the distinctive and well-defined shape of its outer membrane; from *Deflandrea* Eisenack, *Scriniodinium* Klement, and *Muderongia* Cookson and Eisenack in that the outer membrane has only two opposed prominences (*Scriniodinium* lacks horns; *Deflandrea* has one extremity, a single horn, and the other, two horns; *Muderongia* has four equidistant horns) and from *Deflandrea* and *Scriniodinium* also in that the central body lacks a transverse furrow, these latter genera being undoubtedly encysted dinoflagellates.

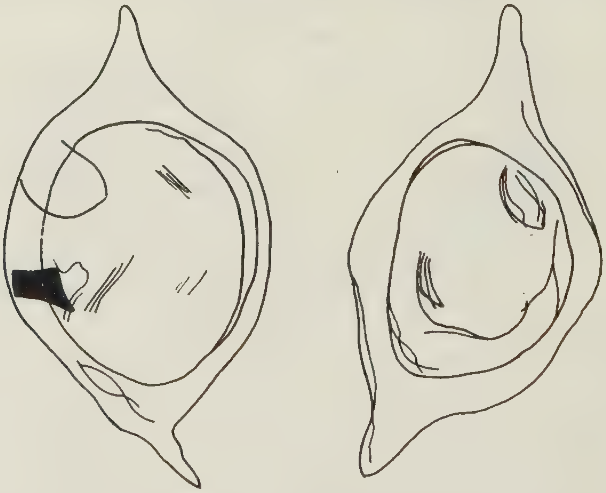
The affinities of this genus are doubtful. It is possible that it comprises encysted dinoflagellates; however, as stated above, the central body shows no transverse furrow or girdle. Deflandre comments on the equally problematical genus *Pterocystidiopsis* (1941): 'Should one see in this organism some peculiar member of the microplankton, or is this on the contrary a spore of a being higher in the organisation? Nothing permits the solving of that question, for the moment.' This comment is equally applicable to the genus *Netrelytron.*

Netrelytron stegastum sp. nov.

Plate 15, fig. 15; text-fig. 14

Holotype. CB81/16/10, 100-foot horizon of Oxford Clay, High Red Cliff, Cayton Bay. *Dimensions.* Holotype: overall length 125 μ, breadth 55 μ, long diameter of inner shell 55 μ, short diameter 45 μ; the paratype figured (CB81/23/18) is of similar dimensions.

Diagnosis. A species of *Netrelytron* having an outer membrane of almost spherical shape, with conical horns arising from it at two opposed extremities. These horns have rounded tips and tend to be inclined rather than vertical in their relation to the surface of the ovoidal central body, to whose long axis their position corresponds.



TEXT-FIG. 14. *Netrelytron stegastum* gen. et sp. nov. The holotype CB81/16/10 and a paratype, CB81/23/18, figured without the investing material. ×600.

Description. All specimens found are invested almost completely in a mass of formless organic matter; this follows the rough outline of the outer membrane and may represent a protective envelope formed around itself by the living organism. Outer membrane thin, devoid of ornamentation. In two specimens seen it is perforated by a roughly oval aperture on one flank, a corresponding gap in the cloak of extraneous material being noted. Character of the ovoidal inner shell difficult to determine; it appears of moderate thickness and devoid of ornamentation save possibly for a very faint granulation. Both inner shell and outer membrane frequently folded in some degree. The type specimen and a paratype are both stained with safranin; however, the two other specimens seen are unstained, having a yellowish-brown hue, the inner shell more strongly coloured than the outer membrane.

Remarks. The perforation in the outer membrane may be interpreted as a pylome, in which case this surface would be termed dorsal (cf. Eisenack 1958). If this interpretation were correct, a relationship to the Order Dinoflagellata would be suggested; however, no aperture was observable in the two other specimens seen, and its constancy cannot be affirmed. Similarly, since only four specimens of this distinctive microfossil have been seen, the constancy of the envelope of organic matter cannot be vouched for. All specimens found derived from the 100-foot Oxford Clay horizon, the material from which was very well oxidized; other microfossils from this horizon rarely show any degree of investment in extraneous material, and it is improbable that all specimens of a relatively smooth form such as this should have become fortuitously enwrapped when hystrichospheres bearing complex spines, such as the two species of *Cannosphaeropsis* present, remain free.

CONCLUSIONS

In the assemblages described eight species of dinoflagellates and sixteen species of hystrichospheres were recognized. *Gonyaulax jurassica* Deflandre proved by far the most abundant dinoflagellate at all horizons, *G. cladophora* Deflandre coming second in abundance. Of the hystrichospheres *Cymatiosphaera parva* Sarjeant is the commonest species in the Kellaways Rock assemblage but is not present in the Oxford Clay assemblages; in these assemblages *Baltisphaeridium pilosum* (Ehrenberg) is the most common species. In addition four genera of organisms *incertae sedis*, presumed microplankton, are present, three of the genera and all six species being described for the first time. Text-fig. 15 shows the distribution of species in the horizons considered, in comparison with their distribution as previously recorded. Progressive change in the character of the microplankton with time is indicated.

Some assessment may be made of the stratigraphic value of the fossil microplankton by comparing this assemblage as a whole with other assemblages described. On the basis of previous published records three species have ranges spanning the Callovian and Lower Oxfordian: *Gonyaulax jurassica* (Bathonian to Kimeridgian) and *G. cladophora* (Bajocian to Kimeridgian), both of which species probably attained their acme in the Oxfordian, and *Micrhystridium inconspicuum* (Bajocian to Upper Cretaceous). Five species were previously known only from lower horizons: *Micrhystridium fragile* and *M. stellatum* (Bajocian to Lower Callovian [Cornbrash]), *M. recurvatum* f. *reducta* (Bathonian), *Membranilarnax ovulum* (Bajocian to Bathonian), and *Cymatiosphaera parva* (Lower Callovian [Cornbrash]). Two species have known ranges from the Middle Jurassic to the Callovian or Lower Oxfordian, but are not recorded from younger sediments: *Pareodinia ceratophora* (Bajocian to Callovian) and *Baltisphaeridium stimuliferum* (Bajocian to Lower Oxfordian). Two species have known ranges from the Lower Oxfordian upwards: *Cannosphaeropsis caulleryi* (Lower Oxfordian to Eocene) and *Hystrichosphaeridium salpingophorum* (Lower Oxfordian to Oligocene). Finally four species have been recorded only from comparable horizons elsewhere: *Scriniodinium crystallinum* (Lower Oxfordian and 'Upper Jurassic' of Australia), *S. galeritum* (Lower Oxfordian), *Baltisphaeridium pilosum* ('Corallian'), and *Cannosphaeropsis aemula* (Lower Oxfordian and 'Upper Jurassic' of Australia).

Thus the known stratigraphic occurrences of fossil microplankton would indicate a position for these horizons within the stratigraphic range Bathonian–Lower Oxfordian;

	Pre-Callovian horizons	*Lower Callovian—Cornbrash of Yorkshire*	*Lower Callovian—Kellaways Rock of Yorkshire*	*Middle–Upper Callovian*	*Lower Oxfordian Oxford Clay of Yorkshire*			*Lower Oxfordian of France*	*Post-Oxfordian horizons*
					Lowest	*25-foot*	*100-foot*		
Gonyaulax jurassica	×	..	×	..	×	×	×	×	×
G. jurassica var. *longicornis*	..	..	..	..	×	..	×	×	..
G. cladophora	×	..	×	..	×	×	×	×	×
G. cladophora var. *multispinosa*	..	..	..	..	..	..	×	..	..
G. acanthosphaera	..	..	..	..	×	..	..	..	..
G. areolata	..	..	..	..	×	..	×	..	..
G. sp.	..	..	..	..	×	..	..	..	..
Scriniodinium crystallinum	..	..	.	..	×	×	×	×	..
S. galeritum	..	..	..	..	..	..	×	×	..
Pareodinia ceratophora	×	..	..	?	..	..	×	..	..
P. ceratophora var. *pachyceras*	..	×	..	..	×	..	..	..	..
Hystrichosphaeridium salpingophorum	..	..	..	..	×	×	..	×	×
H. cf. *truncigerum*	..	..	..	..	..	..	×	..	..
Baltisphaeridium stimuliferum	×	..	..	..	×	×	×	×	..
B. pilosum	..	..	..	..	×	×	×	..	..
B. pilosum var. *longispinosum*	..	..	..	..	×	..	..	..	..
B. cf. *fimbriatum*	..	..	×	..	×	×	×	..	..
B. ehrenbergi var. *brevispinosum*	..	..	..	..	×	..	..	..	..
Cannosphaeropsis caulleryi	..	..	×	..	×	×	×	×	×
C. aemula	..	..	..	..	..	..	×	×	..
Polystephanosphaera calathus	..	..	..	..	×	×	..	..	..
Micrhystridium inconspicuum	×	×	×	..	×	×	×	..	×
M. fragile	×	×	×	..	..	.	..	..	..
M. stellatum	×	×	×	..	×	×	×	..	..
M. recurvatum f. *reducta*	×	..	×	..	×	×	×	..	..
M. cf. *mendax*	..	..	..	..	×	×	..	..	..
? *M. sp.*	..	..	..	..	×	×	×	..	..
Cymatiosphaera teichophera	..	..	..	..	..	..	×	..	..
C. parva	..	×	×	..	..	..	..	..	..
? *C.* sp. indet.	..	..	..	..	..	×	..	..	..
Membranilarnax ovulum	×	..	..	..	×	..	..	..	..
Stephanelytron scarburghense	..	..	..	..	×	..	..	..	..
S. caytonense	..	..	..	..	..	×	..	..	..
S. redcliffense	..	..	..	..	..	..	×	..	..
Antrosphaera calloviensis	..	..	×	..	..	..	..	..	..
Wanaea fimbriata	..	..	..	..	×	×	×	..	..
Netrelytron stegastum	..	..	..	..	..	..	×	..	..

TEXT-FIG. 15. Known stratigraphic distribution of fossil microplankton species present in the Yorkshire assemblages.

this, of course, corresponds with the stratigraphic position as determined by macrofossils, a satisfactory degree of correlation in view of the present paucity of knowledge of the fossil organic-shelled microplankton.

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REFERENCES

COOKSON, I. C. and EISENACK, A. 1958. Microplankton from Australian and New Guinea Upper Mesozoic sediments. *Proc. Roy. Soc. Victoria*, **70**, 19–79, 12 pl.

DEFLANDRE, G. 1935. Considerations biologiques sur les organismes d'origine planctonique conservés dans les silex de la craie. *Bull. Biol. Fr. et Belg.* **19**, 213–44, 5 pl.

—— 1936–7. Microfossiles des silex crétacés. *Ann. Paléont.* **25**, 151–91, 8 pl.; **26**, 1–55, 10 pl.

—— 1938. Microplancton des mers jurassiques conservé dans les marnes de Villers-sur-Mer (Calvados). *Trav. Stat. Zool. Wimereux*, **13** (Vol. Jub. M. Caullery), 153–200, 7 pl.

—— 1941. Microplancton kiméridgien d'Orbagnoux. *Mém. Acad. Sci. Paris.* **65**, 1–32, 7 pl.

—— 1943. Sur les hystrichosphères des calcaires siluriens de la Montagne Noire. *C.R. Acad. Sci. Paris*, **215**, 475–6, 16 fig.

—— 1947. Le problème des hystrichosphères. *Bull. Inst. Oceanogr. Monaco*, no. **918**, 1–23.

—— 1947. Sur quelques micro-organismes planctoniques des silex jurassiques. Ibid., no. **921**, 1–10.

—— 1954. Systématique des hystrichosphaerides: sur l'acception du genre *Cymatiosphaera* O. Wetzel. *C.R. Somm. Soc. Géol. Fr.* 257–9.

DEUNFF, J. 1954. Sur un microplancton du Dévonien du Canada recélant des types nouveaux d'hystrichosphères. *C.R. Acad. Sci., Paris*, **239**, 1064–6.

—— 1955. Un microplancton fossile Dévonien à hystrichosphères du continent Nord-Americain. *Extrait du Bull. Microsc. Appliqué*, (2) **5**, nos. 11–12, 138–49.

DOWNIE, C. 1957. Microplankton from the Kimeridge Clay. *Quart. J. Geol. Soc. Lond.* **113**, 413–34, 1 pl.

EHRENBERG, C. G. 1838. Über das Massenverhältnis der jetzt lebenden Kiesel-infusorien und über ein neues Infusorien-conglom. als Polierschiefer von Jastraba in Ungarn. *Abhand. K. Akad. Wiss. Berlin*, 1836, f. 1, 109–35, 2 pl.

—— 1843. Über einige Jura infusorien-arten des Corallrags bei Krakau. *Monatsber. Akad. Wiss. Berlin*, 61–63.

—— 1854. *Mikrogeologie*. Leipzig. 40 pl.

EISENACK, A. 1935. Mikrofossilien aus Doggergeschieben Ostpreussens. *Zeitschr. für Geschiebeforsch.* **17**, 167–84, 2 pl.

—— 1936. Dinoflagellaten aus dem Jura. *Ann. Protist.* **5**, 59–64, 1 pl.

—— 1957. Mikrofossilien in organischer substanz aus dem Lias Schwabens. *Neu. Jb. Geol. Pal. Abh.* **105** (3), 239–49.

—— 1958. Mikroplankton aus dem norddeutschen Apt nebst einiger bemerkungen über fossile Dinoflagellaten. Ibid. **106** (3), 383–422, 8 pl.

GOCHT, H. 1952. Hystrichosphaerideen und andere Kleinlebewesen aus Oligozänablagerungen Nord- und Mitteldeutschlands. *Geologie* **1**, 301–20, 2 pl.

—— 1959. Mikroplankton aus dem nordwestdeutschen Neokom. *Paläont. Zeitschr.* **33**, 50–89, 6 pl.

KLEMENT, K. W. 1957. Revision der gattungszugehörigkeit einiger in die *Gymnodinium* Stein eingestufter Arten jurassischer Dinoflagellaten. *Neu. Jb. Min. u.s.w. Monatshefte*, 408–10.

MERCIER, J. 1938. Micro-organismes du bajocien et du bathonien. *C.R. Somm. Soc. Géol. Fr.*, 114–15.

PASTIELS, A. 1948. Contributions à l'étude des microfossiles de l'Éocène belge. *Mém. Mus. Roy. Hist. Nat. Belg.* **109**, 1–77, 6 pl.

SARJEANT, W. A. S. 1959. Microplankton from the Cornbrash of Yorkshire. *Geol. Mag.* **96**, 329–46, 1 pl.
—— 1960. New Hystrichospheres from the Upper Jurassic of Dorset. *Geol. Mag.* **97**, 137–44.
VALENSI, L. 1953. Microfossiles des silex du Jurassique Moyen. *Mém. Soc. Géol. Fr.* **68**, 1–100, 16 pl.
WETZEL, O. 1933. Die in organischer substanz erhaltenen mikrofossilien des Baltischen Kreide-Feuersteins. *Palaeontographica*, **77**, 141–98 and **18**, 1–110, 7 pl.
WHITE, H. H. 1842. On fossil Xanthidia. *Microscop. Jnl.* **11**, 35–40, 1 pl.

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PERMIAN PELECYPODS NEWLY RECORDED FROM EASTERN AUSTRALIA

by J. M. DICKINS

ABSTRACT. *Atomodesma* (*Atomodesma*) *bisulcata sp.* nov., *Pseudomyalina* sp., and *Oriocrassatella queenslandica* sp. nov. are described from Queensland, and Etheridge jun.'s figured specimen of *Sanguinolites concentricus* (Etheridge sen.) is referred doubtfully to *Pyramus*. *Atomodesma* (*Aphanaia*) is recorded from Queensland and *Schizodus* from Queensland and New South Wales. *Atomodesma*, *Pseudomyalina*, and *Oriocrassatella* have not previously been described from Eastern Australia. On the basis of the pelecypod fauna the Cattle Creek Formation of Queensland is regarded as most likely of early Artinskian (Lower Permian) age and the Crocker Formation, which is considered to be the equivalent of the Mantuan *Productus* Bed, is regarded as of Kungurian to Kazanian age.

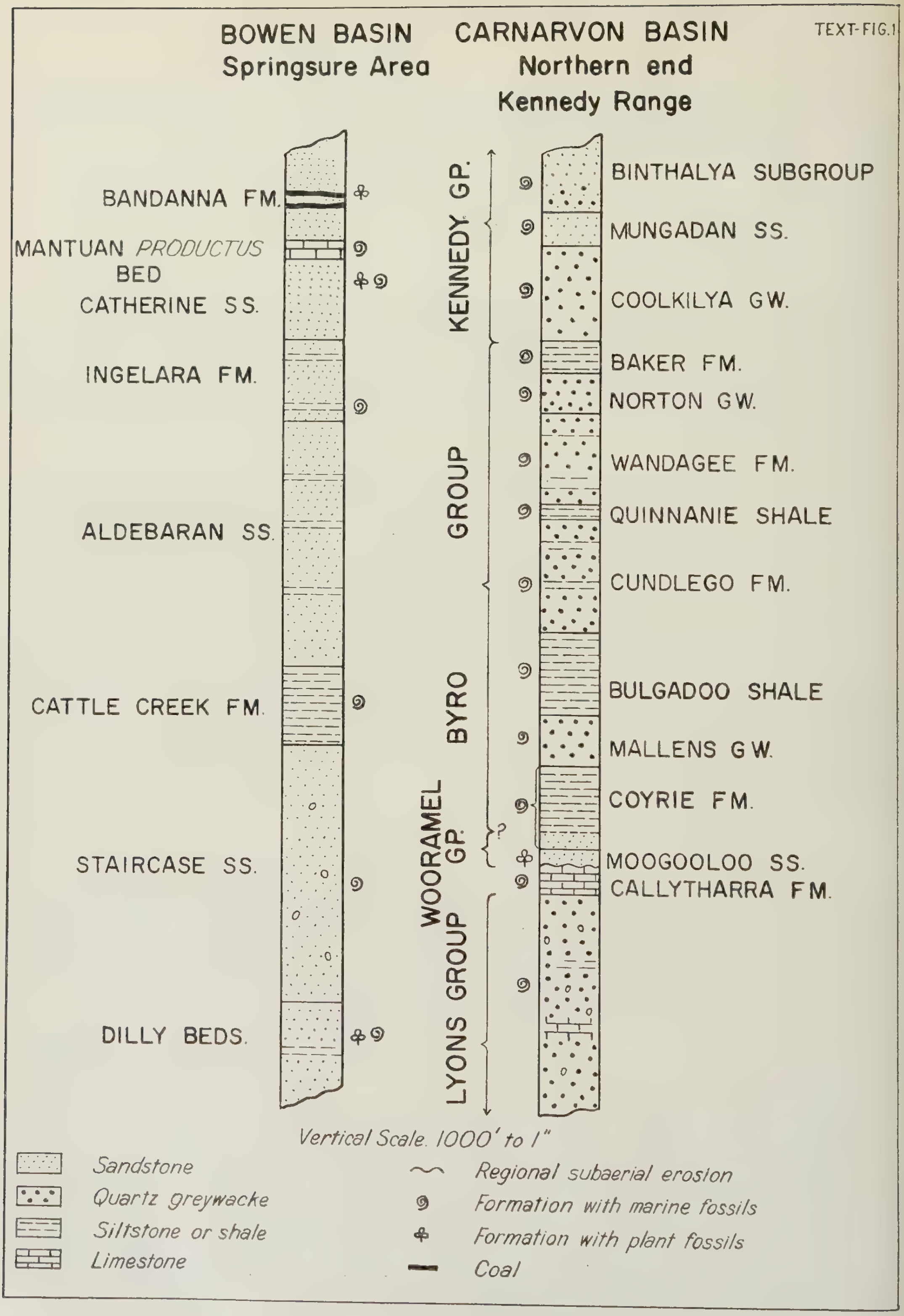
DURING an examination of the collections of the Geological Museum of the University of Queensland, Brisbane, several genera or subgenera hitherto unrecognized in Eastern Australia, were identified. They are of importance for the correlation of the Permian rocks of Queensland, particularly of the Bowen Basin, with those of Western Australia and elsewhere. The genera or subgenera described are *Atomodesma* (*Atomodesma*), *Pseudomyalina*, and *Oriocrassatella*. *Schizodus* (*sensu lato*), although it has not so far been described, is represented in Queensland and New South Wales by a number of species, but they require an extensive study which is outside the scope of this paper. In addition *Atomodesma* (*Aphanaia*), which occurs in New South Wales, is also found in Queensland, but the specimens are fragmentary and are not described here. Because of its possible relationship to *Oriocrassatella*, the figured specimen of *Sanguinolites concentricus* (Etheridge sen.) (1872, p. 328, pl. 13, fig. 2), Etheridge jun. (1892, p. 281, pl. 43, fig. 7) is refigured and described.

PERMIAN ROCKS IN QUEENSLAND AND WESTERN AUSTRALIA

The succession in the Springsure (eastern) area of the Bowen Basin, taken from Hill (1957), is shown in the accompanying text-figure and is tabulated below. Earlier accounts include Hill (1955) and Webb (1956). Hill (1957, p. 12) says, 'the successive rich marine faunas, Dilly, Cattle Creek, Ingelara and Mantuan must form the standard for the correlation of the entire Queensland Permo-Carboniferous'.

8. *Bandanna Formation* 1,000 feet
Shale, sandstone, calcareous sandstone and sandy limestone, with coal and oil shale seams and plant fossils.
7. *Mantuan* PRODUCTUS *Bed* 100 feet
Limestone to calcareous sandstone, with brachiopods, bryozoans and corals.
6. *Catherine Sandstone* 400–700 feet
Sandstone and occasional calcareous sandstone; with brachiopods and plants.
5. *Ingelara Formation* 90–500 feet
Shale, sandstone, thin bands of limestone, with a rich marine fauna.
4. *Aldebaran Sandstone* 1,500–2,500 feet
Sandstone with quartz pebbles, intercalated shale and clay, no fossils recorded.

[Palaeontology, Vol. 4, Part 1, 1961, pp. 119–130, pl. 16.]


TEXT-FIG.1
BOWEN BASIN
Springsure Area
CARNARVON BASIN
Northern end
Kennedy Range
BANDANNA FM.
MANTUAN PRODUCTUS BED
CATHERINE SS.
INGELARA FM.
ALDEBARAN SS.
CATTLE CREEK FM.
STAIRCASE SS.
DILLY BEDS.
KENNEDY GP.
BYRO GROUP
WOORAMEL GP.
?
LYONS GROUP
BINTHALYA SUBGROUP
MUNGADAN SS.
COOLKILYA GW.
BAKER FM.
NORTON GW.
WANDAGEE FM.
QUINNANIE SHALE
CUNDLEGO FM.
BULGADOO SHALE
MALLENS GW.
COYRIE FM.
MOOGOOLOO SS.
CALLYTHARRA FM.
Vertical Scale. 1000′ to 1″
Sandstone
Quartz greywacke
Siltstone or shale
Limestone
Regional subaerial erosion
Formation with marine fossils
Formation with plant fossils
Coal

TEXT-FIG. 1

3. *Cattle Creek Formation* 500 feet in surface outcrop
Shale, marl, marly limestones, with a rich marine fauna.
2. *Staircase Sandstone* 1,600 feet
Sandstone with quartz conglomerate and clay. Brachiopods, pelecypods, and gastropods.
1. *Dilly Beds* 2,000 feet exposed
Sandstone, shale, mudstone, calcareous sandstone with marine fossils and some plants.

Hill (1955) correlated the beds at Mount Britton (Homevale Beds) approximately with the Cattle Creek Formation.

Webb (1956) extended the Cattle Creek Formation downward from subsurface evidence and the Cattle Creek Formation of Webb may include the Staircase Sandstone and the Dilly Beds or part of the Dilly Beds of Hill.

The succession at the northern end of the Kennedy Range in the Carnarvon (northwest) Basin, Western Australia, is derived from Condon (1954) and McWhae, Playford, Lindner, Glenister, and Balme (1958), somewhat modified by later work (see Konecki, Dickins, and Quinlan 1959).

14. *Binthalya Subgroup* 1,725 feet
Quartz sandstone and quartz greywacke, with a poor marine fauna.
13. *Mungadan Sandstone* 184 feet
Quartz sandstone, with a poor marine fauna.
12. *Coolkilya Greywacke* 625 feet
Predominantly quartz greywacke, with many marine fossils; mainly molluscs and brachiopods. [The 'greywackes' in the succession are in fact all quartz greywackes (defined by Condon (1953, p. 9) as an arenite 'composed of more than 50% quartz, 10–30% fine-grained matrix, and 0–20% feldspar').]
These three subdivisions are placed in the Kennedy Group.
11. *Baker Formation* 210 feet
Siltstone and quartz greywacke.
10. *Norton Greywacke* 250 feet
Predominantly quartz greywacke.
9. *Wandagee Formation* 545 feet
Siltstone and quartz greywacke, with a very rich marine fauna in places.
8. *Quinnanie Shale* 85 feet
Shale and thin quartz greywacke.
7. *Cundlego Formation* 700 feet
Quartz greywacke and siltstone, with some calcareous beds.
6. *Bulgadoo Shale* 500 feet
Siltstone, carbonaceous shale, and thin quartz greywacke.
5. *Mallens Greywacke* 300 feet
Predominantly quartz greywacke.
4. *Coyrie Formation* 500 feet
Siltstone and quartz greywacke.

The above seven formations, together with the top of the Coyrie Formation, are placed in the Byro Group.

In the top part of the Coyrie Formation and the other formations of the Byro Group, marine fossils are well represented and in places rich faunas are present. Fossils include brachiopods, bryozoans, foraminifera, ostracods, corals, trilobites, pelecypods, gastropods, a few ammonoids, blastoids, crinoids, and shark and fish remains. Wood and leaves also occur. In the lower part of the Coyrie Formation marine fossils are poorly represented or absent.

3. *Moogooloo Sandstone* 122 feet
   Mainly quartz sandstone. Marine fossils poorly represented. [Name proposed by Condon (in McWhae *et al.* 1958, p. 66) to replace the Wooramel Sandstone as previously used by him in the Carnarvon Basin proper. The bottom arenaceous part of the Coyrie Formation and the Moogooloo Sandstone together represent the Wooramel Group of the Byro area.]
2. *Callytharra Formation* 250–400 feet
   Limestone, quartz greywacke and siltstone, with a rich marine fauna throughout.
1. *Lyons Group* ?3,700 feet
   Silty and sandy 'tillite', quartz greywacke and siltstone, boulders beds, marine fossils in places.

The Norton Greywacke appears to be the same formation as the Nalbia Sandstone of Teichert (1950; 1952) and the Baker Formation is apparently the bottom part of Teichert's Coolkilya Sandstone. Teichert (1957) and McWhae *et al.* (1958, p. 69) have suggested that the name Norton Greywacke is a synonym of Nalbia Greywacke.

McWhae *et al.* (1958, p. 67) have also suggested a return to the use of Teichert's (1950, p. 1791) name 'Coyrie Shale' for the upper argillaceous part of the Coyrie Formation placed in the Byro Group and that the arenaceous bottom part of the Coyrie Formation placed in the Wooramel Group be named as a separate formation.

In the Fitzroy Basin of Western Australia the lower marine beds of the Liveringa Formation (Lightjack Member) are correlated with the Baker Formation and Coolkilya Greywacke and are considered to be of Upper Artinskian to Kungurian age (see Thomas and Dickins 1954). The upper marine beds (Hardman Member) of the Liveringa Formation are considered to be of Upper Permian (possibly Tatarian) age. The lower and upper marine beds are separated by a plant-bearing sequence.

Correlation. The ages of the Western Australian formations have been discussed by, *inter alia*, Thomas and Dickins (1954). Among the forms which first appear in the Callytharra Formation and its equivalents are *Atomodesma*, *Pseudomyalina*, and *Oriocrassatella*. On the other hand some genera, notably *Eurydesma*, have only been found in the Lyons Group (Dickins 1957). But in Queensland the beds at Mt. Britton, *Atomodesma* (= *Aphanaia*) and *Pseudomyalina* occur with *Eurydesma*; and in the Springsure area, *Pseudomyalina* and *Oriocrassatella*[1] occur in strata mapped as Dilly Beds which certainly are not as young as the Cattle Creek Formation in the restricted sense of Hill. An advanced species of the *Aviculopecten subquinquelineatus* line has been found in the outcropping Cattle Creek beds and the beds at Mt. Britton: in the Carnarvon Basin species of this type have not been found below the Byro Group.

This evidence on the whole suggests that the Cattle Creek Formation is of the same age as, or more likely slightly younger than, the Callytharra Formation which is generally regarded as lowermost Artinskian (see Thomas and Dickins 1954) though it may possibly be uppermost Sakmarian. So the Cattle Creek Formation is almost certainly early Artinskian. Other authors (Maxwell 1954; Hill 1955) have reached the same general conclusion although Hill suggested a slightly older age.

If the Cattle Creek Formation is Artinskian, this supports a previous suggestion (Dickins 1957, p. 18) that *Eurydesma* may have slightly different ranges in different places; it survived longer in Queensland than in Western Australia.

[1] Maxwell (1959) records *Schizodus* and *Oriocrassatella* from the Rands and Burnett Formations of the Yarrol Basin, which he refers to the Upper Carboniferous and Lower Permian (Sakmarian) respectively.

The correlation of the Ingelara Formation is considered in detail in the following paper; it is correlated with the upper part of the Byro Group (Cundlego–Baker Formations) on the evidence of *Platyteichum* and *Glyptoleda* and is considered to be of late Artinskian age.

An *Atomodesma* with two anterior grooves, *A. bisulcata* sp. nov. was found in beds in the Crocker Formation, which are considered (S. S. Derrington, pers. comm.) to be the equivalent of the Mantuan *Productus* Bed. A species with one anterior groove, *A. exarata* Beyrich, is found in the Baker and Coolkilya Formations of the Carnarvon Basin and the lower marine beds (Lightjack Member) of the Liveringa Formation in the Fitzroy Basin (Dickins 1956); and an undescribed form with three grooves is present in the upper marine beds (Hardman Member) of the Liveringa Formation. A two-grooved form might be expected to occur between the Lightjack and Hardman Members, thus suggesting the Crocker Formation is Kungurian to Kazanian in age. Two-grooved forms, indeed, have already been recorded from the Basleo Beds of Timor (Wanner 1922). The Basleo Beds appear to be of Kazanian age (see Ruchencev 1956, table 4). Popov (1957) also records a two-grooved *Atomodesma* from north-eastern Siberia which he refers to *A. variabilis* Warner 1922 and considers to be from beds of Kazanian age.

Campbell (1959, p. 341, 342) has reached the same conclusion for the age of the uppermost marine beds in the Bowen Basin, Queensland.

SYSTEMATIC DESCRIPTIONS

Family MYALINIDAE Frech

Genus ATOMODESMA Beyrich 1864

Type species. Atomodesma exarata Beyrich (1864, p. 71, pl. 3, figs. 4*a*, *b*) by subsequent designation of Wanner (1922, p. 63).

Discussion. The relationship of *Atomodesma* to *Posidionella* de Koninck 1885 from the Carboniferous and *Aphanaia* de Koninck 1877, *Maitaia* Marwick 1935, *Kolymia* Licharew 1941, and *Intodesma* Popov 1958, is rather unsatisfactorily understood. It is proposed discussing this in detail elsewhere but the following comments seem pertinent here. In 1956 (p. 23) I proposed that *Aphanaia* be placed in synonymy with *Atomodesma*. Later Waterhouse (1958) showed that, as in *Maitaia*, specimens of *Atomodesma* from Timor, including *A. exarata*, had more than one groove on the ligament area; accordingly he placed *Maitaia* in synonymy with *Atomodesma*, and left the position of *Aphanaia* unresolved until it was found whether or not it had an umbonal septum. I have now examined specimens of the type species, *Aphanaia mitchelli* (M‘Coy), in the Australian Museum, Sydney, and an umbonal septum is present. Waterhouse (1959) proposes that *Aphanaia* and *Kolymia* be regarded as subgenera of *Atomodesma*, and places *Maitaia* and *Intodesma* in synonymy with *Aphanaia*. He regards the longitudinal grooves in the ligament area as formed by strongly developed growth ridges, and not as analogous with the ligament grooves of *Myalina*. I agree with this interpretation and Waterhouse's proposal to regard *Aphanaia* and *Kolymia* as subgenera of *Atomodesma*. The species described below has two anterior grooves or plications and is placed in the subgenus *Atomodesma*.

Atomodesma (*Atomodesma*) *bisulcata* sp. nov.

Plate 17, figs. 15–19

Diagnosis. Of medium size, distinguished by two anterior grooves and the elongation at about right angles to the hinge-line.

Description. Holotype (impression of a right valve). The shell is oval elongated normal to the hinge-line. The anterior-ventral part extends for a considerable distance in front of the umbo. (This feature does not show in the other specimens which are, however, considerably smaller.) A marked feature is the strong development of two anterior grooves which are shallow in the middle part of the shell and become deeper towards the margin; the posterior groove is the deeper. The umbo is not preserved. No posterior groove or sulcus is visible. The concentric furrows and rugae are well marked and fairly regular. The ligamental structure is not shown.

Paratype A, a right valve, shows the umbo and two anterior grooves. In Paratype B, also a right valve, the umbo is missing. The posterior of the anterior grooves is distinct, but, as might be expected in a young shell, the front groove is poorly developed.

Dimensions (in mm.)

	Length	*Height*	*Width*
Holotype (QUM F27,124) .	31	40	11
Paratype A (QUM F27,121) .	17	19	5
Paratype B (QUM F27,122) .	12	14	4

Occurrence. The material consists of four specimens from a single locality, 6·5 miles south of Tolmies (abandoned); it was collected by S. S. Derrington and D. M. Traves of Mines Administration Pty. Ltd. from 15–20 feet above the base of the Crocker Formation (Derrington and Morgan 1959). This formation is considered by the Mines Administration geologists to be the equivalent of the Mantuan *Productus* Bed. The fossils are contained in a white to grey medium to coarse-grained quartz sandstone which has some kaolinized feldspar grains.

Discussion. Two-grooved forms have been recorded from Timor, where Wanner (1922) assigns specimens from Basleo and 'Abbang von Niki Niki gegen Noil Fatoe' to *A. variabilis* Wanner 1922, and specimens from Noil Mahatissa to *A. elongata* Wanner 1922. Although Wanner considers *A. elongata* to be of Lower Triassic age this seems unlikely (see Dickins 1956, p. 25). The Queensland species differs considerably in shape from the Timor species which are all obliquely elongated. In the elongation of the shell, however, it is similar to *Atomodesma mitchelli* (M'Coy) 1847, Dickins (1956, pl. 4, fig. 1) from the Permian of New South Wales. The age of the Queensland species is considered to be Kungurian or Kazanian.

Genus PSEUDOMYALINA Dickins 1956

Type species. *Pseudomyalina obliqua* Dickins (1956, p. 26, pl. 3, figs. 1–7) by original designation (ibid., p. 25).

Pseudomyalina sp.

Plate 16, figs. 11–12

Description. Two specimens are figured. One shows the shape and the other is a fragmentary individual showing the hinge structure and the external ornament. In the first specimen the elongation is only slightly oblique to a line at right angles to the hinge; in shape it is not unlike species of *Atomodesma* (*Aphanaia*), but the beak and the umbonal fold are turned over towards the front, so that the anterior margin is concave inwards below the beak to an extent not known in *Atomodesma*, where the anterior margin immediately below the beak is usually straight or convex. The second specimen is the umbonal part of an external impression; five longitudinal grooves are visible on the flattish ligament area of the right valve. On the left valve, distinct radial ornament is developed in addition to the concentric growth ornament. Two orders of radial ribbing are formed, either by subdivision or intercalation.

Dimensions (in mm.)

	Length	*Height*	*Thickness*
Figured Specimen A, left valve (QUM F27,405) . .	65	59	11

Occurrence. Figured Specimen A, KOE6, Orion Creek, 6 miles west of the Springsure–Rolleston Road, Springsure 4-mile map sheet 643,978, mapped as Dilly Beds, but may be equivalent of the lower part of the Staircase Sandstone (D. Hill, pers. comm.). Figured Specimen B (QUM F21,006), Homevale Bed 9, ¼ mile east of Homevale Station, Mt. Britton 1-mile map sheet 200,198 (from unpublished work of Campbell and Tweedale; G. W. Tweedale, pers. comm.).

Discussion. Pseudomyalina is represented in the collection in Queensland only by a few fragmentary specimens, so that the species cannot be accurately described or compared with Western Australian species. In *Pseudomyalina* the prisms which make up the outer shell layer are readily visible to the naked eye, whereas in specimens of *Atomodesma* I have examined, they are hardly visible. This may be useful for distinguishing shell fragments of the two genera.

Family CRASSATELLIDAE Dall

Genus ORIOCRASSATELLA Etheridge jun. 1907

Type species. Oriocrassatella stokesi Etheridge jun. (1907, p. 9, pl. 6, figs. 2–5) by monotypy.

Synonym. Procrassatella Yakovlev 1928 (type species *Schizodus planus* Golovkinsky (1868, p. 358, pl. 3, figs. 21–23) by monotypy).

Discussion. Since I gave additional information on *Oriocrassatella* (Dickins 1956, p. 32) Newell (1958) has discussed in detail the character of *Oriocrassatella* and its relationship to *Procrassatella*. After Newell's analysis I have no hesitation in placing *Procrassatella* in synonymy with *Oriocrassatella*. For convenience Newell's diagnosis (1958, p. 6) is reproduced:

'Lenticular, ovoid to elongate, crassatelliform, unornamented shells without well-defined lunule and escutcheon; ligament furrow opisthodetic, internal, separated by a heavy septum from a triangular resilifer; 3*a* and 4*b* narrow.

Dental formula:

AI3a—3b—rsl—PIII
AII—2—4b rsl PII'

3a may be poorly developed or possibly absent altogether in some specimens and AI and AII poorly developed.

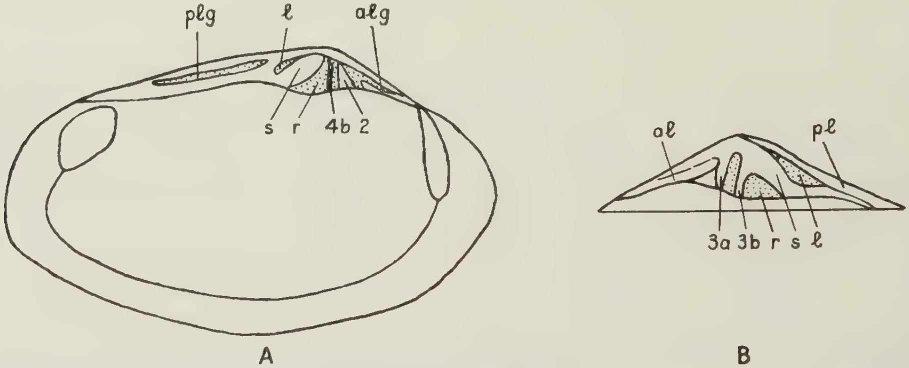
Oriocrassatella queenslandica sp. nov.

Plate 16, figs. 3–10

Diagnosis. Shell rather elongated, anterior and posterior lateral teeth well developed; septum separating ligament from resilium very heavy. Scar of the posterior adductor muscle high on the posterior umbonal ridge.

Description. Compared with other species these shells are rather elongated. The external ornament is composed of concentric growth-lines; low concentric rugae separated by shallow furrows are developed, especially towards the back. The growth-lines are evenly rounded except towards the back where they bend sharply over the posterior umbonal ridge and run towards the cardinal margin, forming a posterior truncation of the shell. Internally the anterior adductor muscle is oval, elongated in a dorso-ventral direction. The posterior muscle is also oval but less elongated; the direction of elongation is at only a slight angle to the posterior part of the cardinal margin and almost parallel to the low umbonal ridge which runs down from the umbo towards the junction of the ventral and posterior margins.

The left valve shows distinct grooves for the reception of an anterior and posterior lateral tooth of the right valve. The septum separating the ligament from the resilium



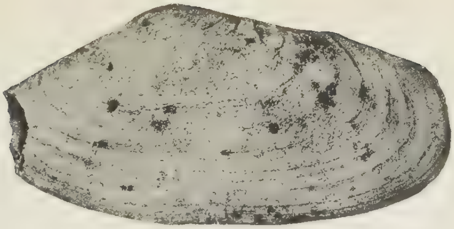
TEXT-FIG. 2. *Oriocrassatella queenslandica* sp. nov. Diagrammatic restoration ×1 approx. A, Hinge and musculature of left valve. B, Hinge of right valve. *plg*, groove for posterior lateral tooth; *l*, ligament; *s*, septum; *r*, resilium; *alg*, groove for anterior lateral tooth; *al*, anterior lateral; *pl*, posterior lateral; 2, 3*a*, 3*b*, and 4, cardinal teeth.

EXPLANATION OF PLATE 16

Figs. 1–2. *Pyramus? concentricus* (Etheridge sen.) 1872, ×1, Geol. Surv. of Qld. F1557. 1, Lateral view. 2, Dorsal view.

Figs. 3–10. *Oriocrassatella queenslandica* sp. nov., ×1. 3–4, Holotype, Queensland University Museum (QUM) F26,795, front and lateral view. 5, Paratype D, QUM26,853, latex impression of hinge. 6, Paratype C, QUM26,790, internal impression showing muscle scars and pallial line. 7–8, Paratype A, QUM F26,794, dorsal and lateral views. 9–10, Paratype B, QUM F26,786, latex impression of hinge, and lateral view.

Figs. 11–12. *Pseudomyalina sp.*, ×1. 11, Figured Specimen B, QUM F21,006, plasticine impression showing lateral view of dorsal part of left valve and ligament area of right valve. 12, Figured specimen A, QUM F27,405, lateral view of a left valve.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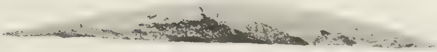
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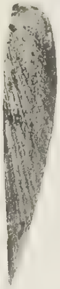
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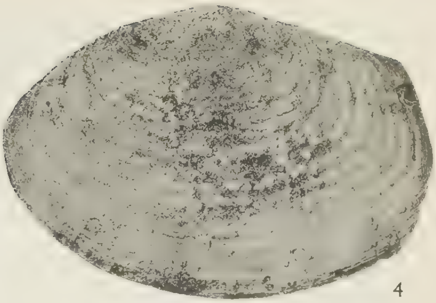
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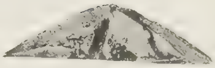
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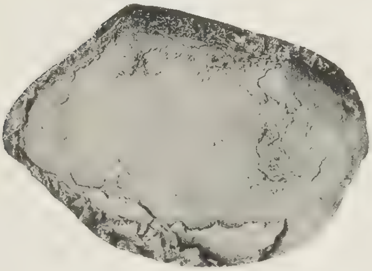
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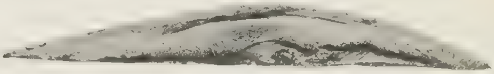
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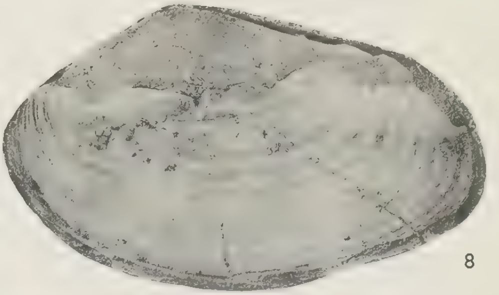
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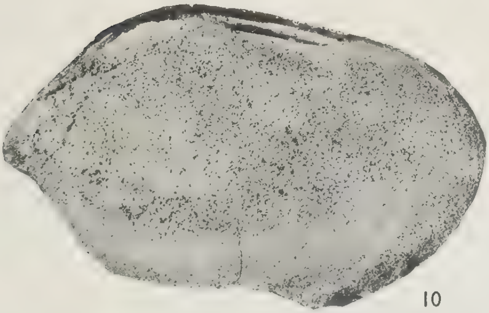
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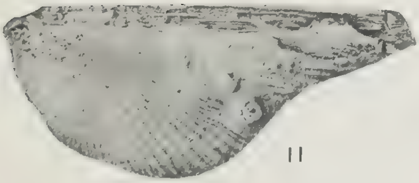
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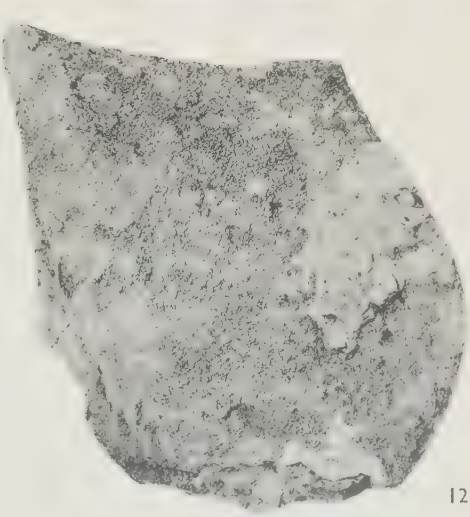
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DICKINS, Permian Pelecypods

is very thick. The posterior cardinal tooth is distinct and separated from the anterior cardinal tooth by a groove for the posterior cardinal tooth of the right valve. The anterior cardinal is incompletely preserved but was probably bifid as in other species. In the right valve, two cardinal teeth are also visible, the anterior of which is poorly differentiated from the front part of the cardinal plate. During the growth of the shell the ligament moved from an external to an internal position as shown by the nymph formed by the top part of the septum. The species has the full dentition found in '*Procrassatella*'.

Dimensions (in mm.)

	Length	*Height*	*Width*
Holotype (QUM F26,795) .	56 approx.	39	7
Paratype A (QUM F26,794) .	64	37	8
Paratype B (QUM F26,786) .	62 approx.	42	5
Paratype D (QUM F26,853) .	50	34 approx.	8 approx.

Occurrence. Holotype and Paratypes A and B, KOE6, Orion Creek, 6 miles west of the Springsure–Rolleston road, Springsure 4-mile map sheet 643,978. Paratype C (QUM No. 26,790), KOE 5, Orion Creek, 5 miles west of Springsure–Rolleston road, Springsure 4-mile map sheet 645,978. KOE6 is stratigraphically lower than KOE5 and both are mapped as Dilly Beds but may be from the equivalent of the lower part of the Staircase Sandstone (D. Hill, pers. comm.). Paratype D, E. A. Webb Collection outcrop 464, 3 miles east-north-east of Birralee Hill, in the Glendoo Sandstone, the marine member of the Collinsville Coal Measures.

Discussion. Oriocrassatella queenslandica is readily separable from *O. stokesi* by its greater transverse elongation, the heavier septum which separates the ligament from the resilium, and the higher position of the posterior adductor muscle. The Queensland species also appears to be rather different from *Oriocrassatella brenensis* (Reed) (1932, p. 58, pl. 7, figs. 1 and 2) and *O. intermedia* (Reed) (1932, p. 59, pl. 7, figs. 3–5; pl. 8, fig. 8) from the Permian of Kashmir, but *O. lapidaria* Reed (1932, p. 57, pl. 7, fig. 7) has similar dimensions and apparently the posterior muscle is in a similar position. Reed's material, however, does not allow a reliable comparison.

Family ?EDMONDIIDAE King 1849

Genus PYRAMUS Dana July 1847

Type species. Pyramus myiformis Dana (1847, p. 57; 1849, p. 697, pl. 6, figs. 4*a–c*) by subsequent designation of Newell (1956, p. 10).

Synonyms. Pyramia Dana (1849, p. 695), variant spelling of *Pyramus; Clarkia* de Koninck (1877, p. 128), based on same type species.

Family position. Newell (1956) proposed placing *Pachydomus Morris* 1845 (= *Megadesmus* Sowerby 1838), *Myonia* Dana 1847, *Pyramus* Dana 1847, in the family Pachydomidae. He regards *Astartila* Dana 1847 as a synonym of *Pachydomus*, *Maeonia* Dana 1849 and *Pachymyonia* Dun 1932 as synonyms of *Myonia*, and *Notomya* M'Coy November 1847, *Pyramia* Dana 1849, and *Clarkia* de Koninck 1877 as synonyms of *Pyramus*. He discusses the ligamental structure and draws the important conclusion that all are burrowing forms. Many of them do not seem to differ sufficiently from the Edmondiidae to be placed in a separate family, but *Pyramus* is rather transversely elongated and the hinge appears to be rather different from that of *Edmondia* so that it has only been tentatively placed in this family.

Discussion. Notomya is more robust and has a more distinctly developed umbo, and the muscle scars are more strongly marked than in *Pyramus*; and for the present Newell's proposal to regard *Notomya* as a synonym of *Pyramus* is not followed. Similarly it is not proposed to regard *Astartila* as a synonym of *Pachydomus* (= *Megadesmus*).

Pyramus? concentricus (Etheridge sen.) 1872

Plate 16, figs. 1–2

1872 *Edmondia concentrica* Etheridge sen., p. 328, pl. 13, fig. 2.
1892 *Sanguinolites concentricus* Etheridge jun., p. 281, pl. 43, fig. 7.

Description of Etheridge jun.'s figured specimen. As can be seen from the photograph the figure is accurate. Only concentric ornament is present, made up of growth-lines which are more distinctly developed at regular intervals, forming the 'band-like zones' described by Etheridge sen. The change of direction of the growth-lines at the posterior ventral angle is less sharp than that characteristic of *Oriocrassatella*, so that posterior truncation is absent. A slight ridge runs from the umbo to the posterior-ventral angle with a shallow sulcus running to the ventral margin in front of the ridge.

Dimensions (in mm.)

	Length	*Height*	*Width*
Geological Survey of Queensland No. F1557 . .	58	28	6

Occurrence. Gasworks, Gympie, Queensland. Permian.

Discussion. In addition to Etheridge jun.'s specimen, other specimens of this species from Gympie are in the collections of the Geological Survey of Queensland. None of those seen, however, showed any additional features. There is little doubt that Etheridge sen.'s specimen, which also came from Gympie, belongs to the same species; the associated fauna indicates that the beds are of Permian age. Although Reed (1932, p. 58) suggests that *P. concentricus* may belong to *Oriocrassatella*, the considerable transverse elongation, the more central position of the umbo, and the roundness of the posterior margin afford evidence against this conclusion; it appears more likely to belong to *Pyramus*.

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REFERENCES

BEYRICH, E. 1864. Ueber eine Kohlenkalk Fauna von Timor. *Abh. Akad. Wiss. Berl.* 61–98.

CAMPBELL, K. S. W. 1959. The *Martiniopsis*-like Spiriferids of the Queensland Permian. *Palaeontology*, **1**, 333–50.

CONDON, M. A. 1953. Nomenclature of sedimentary rocks—glossary. *Bur. Min. Resour. Aust. Rec.*, 1953/131 (unpubl.).

—— 1954. Progress Report on the geology of the Carnarvon Basin. *Bur. Min. Resour. Aust. Rep.* **15.**

DANA, J. D. 1847. Description of fossils from Australia. *Amer. J. Sci.* **54,** 151–60.

—— 1849. *In* United States exploring expedition during the years 1838–1842, under the command of Charles Wilkes, U.S.N.; **10,** *Geology*, 681–713.

DERRINGTON, S. S. and MORGAN, K. H. 1959. New names in Queensland Stratigraphy. Part I, Central Bowen Syncline. *Aust. Oil Gas J.* **5,** (8), 33–35.

DICKINS, J. M. 1956. Permian Pelecypods from the Carnarvon Basin, Western Australia. *Bur. Min. Resour. Aust. Bull.* **29.**

—— 1957. Lower Permian Pelecypods and Gastropods from the Carnarvon Basin, Western Australia. Ibid. **41.**

ETHERIDGE, R., jun. 1892. *In* JACK, R. L. and ETHERIDGE, R., jun., *Geology and Palaeontology of Queensland and New Guinea.* Brisbane and London.

—— 1907. Official contributions to the palaeontology of South Australia. *S. Aust. parl. Pap.* **55** (1906), Supp., 1–21.

ETHERIDGE, R., sen. 1872. Description of the Palaeozoic and Mesozoic fossils of Queensland. *Quart. J. geol. Soc. Lond.* **28,** 317–60.

GOLOVKINSKY, N. A. 1868. *Materialen zur Geologie Russlands,* **1,** 273–415, St. Petersburg (not seen).

HILL, D. 1955. Contributions to the correlation and fauna of the Permian in Australia and New Zealand. *J. geol. Soc. Aust.* **2,** 83–107.

—— 1957. Explanatory Notes, Springsure, 4-mile Geological Series. *Bur. Min. Resour. Aust., Note Ser.* **5.**

KONECKI, M. C., DICKINS, J. M., and QUINLAN, T. 1959. The geology of the coastal area between the Lower Gascoyne and Murchison Rivers, Western Australia. *Bur. Min. Resour. Aust. Rep.* **37.**

KONINCK, L. G. DE. 1877. Recherches sur les Fossiles paléozoïques de la Nouvelles-Galles du Sud (Australie). *Mém. Soc. roy. Sci. Liége*, **2,** 2 (trans. into English as *Mem. geol. Surv. N.S.W., Palaeont.* **6,** 1898).

—— 1885. Faune du Calcaire Carbonifère de la Belgique, 5^{e} partie, Lamellibranches. *Ann. Mus. Hist. nat. Belg.* **11.**

LICHAREW, B. K. 1941. *In* LICHAREW, B. K. and EINOR, O. L., On the problem of the age of the Upper Palaeozoic deposits of the south-east part of the Kolyma Basin. *Acad. Sci. U.S.S.R. Dokl.* **31** (2), 150–2.

M'COY, F. 1847. On the fossil botany and zoology of the rocks associated with the coal of Australia. *Ann. Mag. nat. Hist.*, ser. 1, **20,** 145–57; 226–36; 298–312.

MCWHAE, J. R. H., PLAYFORD, P. E., LINDNER, A. W., GLENISTER, B. F., and BALME, B. E. 1958. The stratigraphy of Western Australia. *J. geol. Soc. Aust.* **4** (2).

MARWICK, J. 1935. Some new genera of the Myalinidae and Pteriidae of New Zealand. *Trans. roy. Soc. N.Z.* **65,** 295–303.

MAXWELL, W. G. H. 1954. *Strophalosia* in the Permian of Queensland. *J. Paleont.* **28** (5), 533–59.

—— 1959. New names in Queensland Stratigraphy, Part II, Yarrol Basin. *Aust. Oil Gas J.* **5** (9), 29–31.

NEWELL, N. D. 1956. Primitive Desmodont Pelecypods of the Australian Permian. *Amer. Mus. Nov.* **1799.**

—— 1958. A note on Permian Crassatellid Pelecypods. Ibid. **1878.**

POPOV, U. N. 1957. Some Permian Pelecypods, Gastropods and Ammonites of Verchoyan. *Sci. Inst. Geol. Arctic, Coll. Pap. Palaeont. Biostrat.* **1,** 45–60 (also in *Mater. Geol. Min. Resour. N.E. U.S.S.R.*, 1958 (12), 137–50).

REED, F. R. C. 1932. New fossils from the Agglomeratic Slate of Kashmir. *Palaeont. Indica*, N.S. **20,** 1.

RUCHENCEV, V. E. 1956. Lower Permian Ammonites of the Southern Urals. II. Ammonites of the Artinskian Stage. *Trudy Pal. Inst. Acad. Sci. U.S.S.R.* **60** (in Russian).

SOWERBY, J. 1838. Fossils, *in* T. L. MITCHELL, *Three expeditions into the interior of Australia*, 15.

TEICHERT, C. 1950. Some recent additions to the stratigraphy of Western Australia. *Bull. Amer. Ass. Petrol. Geol.* **25** (3), 371–415.

TEICHERT, C. 1952. Carboniferous, Permian and Jurassic in the North-West Basin, Western Australia. *Congr. géol. int., XIX^{me} sess., Alger. Symp. on Gondwanaland*, 115–35.

—— 1957. Notes on the geology of the Carnarvon (North-west) Basin, Western Australia. *J. roy. Soc. W. Aust.* **40** (2), 65–72.

THOMAS, G. A. and DICKINS, J. M. 1954. Correlation and age of the marine Permian formations of Western Australia. *Aust. J. Sci.* **16** (6), 219–23.

WANNER, C. 1922. Die Gastropoden und Lamellibranchiaten der Dyas von Timor. *Paläont. Timor*, **11** (18).

WATERHOUSE, J. B. 1958. The occurrence of *Atomodesma* Beyrich in New Zealand. *N.Z.J. Geol. Geophys.* **1** (1), 166–77.

—— 1959. Note on New Zealand species of *Atomodesma* Beyrich. Ibid. **2** (2), 259–61.

WEBB, E. A. 1956. Review of exploratory oil wells penetrating Permian sections in Central Queensland, Australia. *Bull. Amer. Ass. Pet. Geol.* **40** (10), 2329–53 (reprinted in *Aust. Oil Gas J.* **3** (7), 3–22, 1957).

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THE GASTROPOD *PLATYTEICHUM* IN THE PERMIAN OF WESTERN AUSTRALIA

by J. M. DICKINS

ABSTRACT. *Platyteichum johnstonei* sp. nov., *P. johnstonei?* and *P.?* sp. nov. are described. The holotype of *P. costatum* Campbell 1953, the type species, and of *P. coniforme* (Etheridge jun.) 1892 are figured and discussed; *P. costatum* may be a synonym of *P. coniforme*. *Platyteichum* Campbell 1953 appears to be closely related to *Mourlonia* de Koninck 1883 and *Mourlonopsis* Fletcher 1958. The species of *Platyteichum* occurring in Western Australia is considered to afford additional evidence for the correlation of the Ingelara Formation of the Bowen Basin of Queensland with the upper part of the Byro Group of the Carnarvon (North-west) Basin of Western Australia.

WITH the exception of those from the lower (Sakmarian) part of the Permian sequence, the marine Permian faunas of Western Australia differ sufficiently from those of Eastern Australia (Queensland, New South Wales, and Tasmania) to be placed in different faunal provinces (see Dickins and Thomas 1959). Thus correlation between the two areas has presented more than usual difficulties. The occurrence in Western Australia of the genus *Platyteichum* Campbell (1953, p. 23) with the type *P. costatum* Campbell (1953, p. 23, pl. 7, figs. 11–14) from the Ingelara Formation of Queensland is of interest, especially as one of the species described resembles the type species. The opportunity is taken of refiguring the holotype and discussing the relationship of the type species, *P. costatum*, to *Mourlonia? coniformis* Etheridge jun. (1892, p. 287, p. 41, fig. 5).

Correlation of the Ingelara Formation with the sequence in Western Australia. Evidence from the pelecypods considered in the previous paper indicates that the Ingelara Formation, which lies stratigraphically between the Cattle Creek Formation and the Mantuan *Productus* Bed, is younger than the Callytharra Formation but is not likely to be much younger than the Coolkilya Formation, the lowest formation of the Kennedy Group. Previous authors (Teichert 1941; Fletcher 1945) have suggested an approximate correlation between the Cundlego Formation of the Carnarvon (North-west) Basin and the Ingelara Formation (for a summary of the stratigraphical sequences in Western Australia and in Queensland see the immediately preceding paper). Fletcher based his conclusion on the occurrence of similar species of *Glyptoleda* in the Cundlego Formation and the Ingelara Formation. Because of its relative position in the Byro Group and its faunal relationship with the other formations of the Group, the Cundlego is regarded as of late Artinskian age (see Thomas and Dickins 1954). With regard to the age of the Ingelara Formation Campbell (1953, p. 5) states: 'Correlation with overseas faunas . . . would thus appear to suggest an age toward the region of the Artinskian–Kungurian boundary.' Campbell's conclusion thus supports that of the previous authors. The present evidence adds additional support to this correlation which may be modified to indicate that the Ingelara Formation can be correlated with the upper part of the Byro Group (Cundlego–Baker Formations).

In undescribed *Glyptoleda*-like forms from the lower part of the Byro Group, the V-ribbing characteristic of *Glyptoleda* is poorly developed, and forms with complex

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ribbing similar to those of the Ingelara Formation are found in the Cundlego and Wandagee Formations. The species of *Platyteichum* which resembles *P. costatum* is found in the Wandagee Formation, the Norton Greywacke, and possibly the Coolkilya Greywacke. Another rather different species is found in the Norton Greywacke and in the younger Coolkilya Greywacke of the Kennedy Group.

Relationship of PLATYTEICHUM *to some other Pleurotomariid genera.* Although *Platyteichum* resembles *Mourlonia*, it differs especially in having a flat upper whorl profile, whereas *Mourlonia* has a gently convex upper whorl. On the other hand it differs considerably from such genera as *Peruvispira* and *Ptychomphalina*. (The relationship of *Mourlonia* and *Ptychomphalina* is being dealt with elsewhere (Dickins 1961).) Its whorl cross-section is rounded and its outline simple; the ornament is composed of both spiral elements and elements parallel to the growth-lines and may have nodes where the two intersect. The spiral elements are simple, comprising threads which are more or less equidistant and of equal prominence. The umbilicus, as in *Mourlonia*, may be closed in the adult and a 'false umbilicus' may be present. *Platyteichum* also resembles *Mourlonopsis* Fletcher (1958, p. 129), which appears to differ mainly in having the whorl cross-section entirely convex as in *Mourlonia*, whereas in mature specimens of *Platyteichum* the upper part of the whorl is flat or concave where it rises to meet the previous whorl.

Platyteichum also has some resemblance to *Baylea* de Koninck 1883, which, however, can be readily separated by the marked step-like character of its whorls and the width of its slit-band. Amongst long-established genera it seems to come closest to *Mourlonia* and it is thus significant that in its earlier whorls *Platyteichum* is even closer to *Mourlonia*.

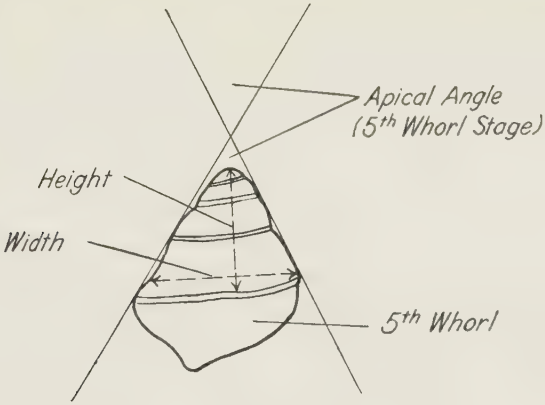
SYSTEMATIC DESCRIPTIONS

Genus PLATYTEICHUM Campbell 1953

Type species. Platyteichum costatum Campbell (1953, p. 23, pl. 7, figs. 11–14) by original designation of Campbell (1953, p. 23).

Discussion. Platyteichum costatum seems to be a synonym of *Mourlonia? coniformis* Etheridge jun. (1892, p. 287, pl. 41, fig. 5) but until further, better-preserved, topotype material of *M.? coniformis* is available, this problem cannot be satisfactorily solved. However, no change in the generic diagnosis would be required. Both the holotype of Campbell's species and Etheridge's single specimen of *M.? coniformis* (Queensland Museum No. F17/1220) are refigured in the accompanying plate. Etheridge records the locality of his specimen as 'Banana Creek, near Banana'; the lithology and the rest of the fauna recorded by Etheridge (1892) from this locality leave no doubt that the specimen is from the Flat Top Formation (Glover 1959) identified by Glover's unpublished report to Mines Administration Pty. Ltd. Dr. D. Hill (pers. comm.) considers that this formation is faunally intermediate between the Ingelara Formation and the Mantuan *Productus* Bed. Collections from this formation are housed in the Museum of the Department of Geology of the University of Queensland. Unfortunately none of the other specimens of *Platyteichum* is better preserved than Etheridge's. Although some have an even lower spire than Etheridge's specimen, many of these are squashed and distorted.

To allow a more accurate comparison of the two specimens, the dimensions have been related to the slit-band of the fifth whorl as shown in the text-figure.



TEXT-FIG. 1. *Platyteichum* Campbell, ×1.

	P. coniforme (Qld. Mus. No. F17/1220)	*P. costatum* (Holotype. Qld. Univ. Geol. Mus. No. F14,181)
Height	12 mm.	15 mm.
Width	19 mm.	20 mm.
Apical angle—fifth-whorl stage . .	63°	61°
third-whorl stage . .	95°	91°
Number of spiral lirae on upper surface of fifth whorl	About 14	About 13
Number of spiral lirae on lower surface of fifth whorl	. .	About 22

The only difference in dimensions of possible significance is that in the height of the spire. This is probably an original feature because, although Etheridge's specimen is squashed laterally, the aboral side does not appear to be markedly distorted. My examination, however, of the type specimens and many other specimens from the type locality indicates considerable variation in the height of the whorl relative to width, and Etheridge's specimen of *P. coniforme* appears to come within these limits of variation. Apart from the dimensions the two appear to be similar in every important respect: the width of the slit-band on the fifth whorl, the number and character of the spiral lirae, and the shape of the growth-lines. In *P. costatum* some of the growth-lines are more distinctly marked than others, whereas they are more uniform in *Platyteichum coniforme*; but this can hardly be regarded as significant. The earlier whorls in both are similar, and differ from the later whorls: the upper surfaces of the second and third whorls are rounded, in contrast to the fifth whorl in which the upper surface is straight or even slightly concave, and the sutures are deeper and more distinctly marked. In these features the fourth whorl is intermediate between the third and fifth. The apical angle of the earlier whorls is considerably greater than in the later whorls. Both the sutures and the shape of the second and third whorls are thus closer to *Mourlonia* than the later whorls.

An examination of the type specimens also shows that the umbilicus was narrow and open at the earlier growth stages but that in at least some mature specimens the umbilicus is closed by callus. Removal of matrix from the holotype shows that the original open umbilicus is closed by callus, but a small external umbilicus ('false umbilicus') is left between the base of the whorl and the columellar lip.

Platyteichum johnstonei sp. nov.

Plate 17, figs. 9–12

Diagnosis. Similar to *P. costatum* (see Plate 17, figs. 4–6), distinguished by having the slit-band slightly higher above the periphery and the whorl cross-section slightly more rounded, lacks the slight but distinct changes in direction of the outline at the bottom of the slit-band and below the slit-band.

Description of holotype. Spire of moderate height, probably originally with five whorls; but the top part of the spire has not been preserved. The sutures are shallow but distinct. The upper surface meets the preceding whorl just below the slit-band at an angle near to that of the apical angle so that the outline is only slightly indented. The earlier whorls are convex and rounded, but the uppermost part of the final whorl is straight or slightly concave. The slit-band is situated slightly above the periphery. The ornament comprises transverse lirae paralleling the growth, and spiral lirae more or less equal to each other in prominence. The lirae bounding the slit-band are hardly more distinct than the rest of the spiral ornament. The growth-lines (or transverse lirae), after leaving the suture, swing backwards in an even curve to the slit-band. Below the slit-band they swing slightly forward and then down over the outer surface of the whorl and backwards over the base in a gentle even curve. Where the transverse and spiral ornament cross, nodes are formed. Most of the base including the umbilical region is not exposed. *Paratypes*. These confirm the features found in the holotype. Paratype B has five whorls; the width relative to the height of the spire is greater than in the holotype but this, at least in part, results from squashing. Paratype C, which is also partly squashed, shows a narrow external umbilicus.

Dimensions (in mm.)

	Height	*Width*	*Apical angle*	*No. of lirae above slit-band on last whorl*	*No. of lirae below slit-band on last whorl*
Holotype . .	22 (approx.)	18	72°	9	17+
Paratype A .	31 (approx.)	24 (approx.)	67°	9	. .
Paratype B .	32	26 (approx.)	88°	. .	. .
Paratype C .	29	22	68°	9	30 (approx.)

Occurrence. Holotype (CPC108),[1] lat. 24° 22′ 26″ S., long. 115° 10′ 00″, 4·5 miles west of south of Merlinleigh Homestead, 97 feet above base of Norton Greywacke. Paratype A (UWA42,115), there is some doubt about the locality from which the specimen was collected but it appears to be from about 2 miles north-north-east of Trig. K56, from top part of Bulgadoo Shale or more likely from bottom part of Cundlego Formation in fault block south of Barrabiddy Creek. Paratype B (UWA42,116), from lower part of Wandagee Formation, west side of Minilya syncline, south of Minilya River, west of Coolkilya Pool. Paratype C (UWA42,117), from lower part of Wandagee Formation, west side of Minilya syncline, south of Minilya River, west of Coolkilya Pool. The description is based on five specimens.

Discussion. P. johnstonei appears to be most closely related to *P. costatum*, from which it can be distinguished by the more rounded whorl outline and by having the slit-band higher and the upper surface slightly less concave. Less closely related is *Pleurotomaria brenensis* Reed (1932, p. 64, pl. 12, figs. 2–4*a*) from the Agglomeratic Slate of Kashmir, which seems also referable to *Platyteichum*. The species is named after Mr. M. H. Johnstone, formerly of the Bureau of Mineral Resources, Geology and Geophysics, and now of West Australian Petroleum Pty. Ltd. Mr. Johnstone has done considerable geological work in Western Australia and collected material from the type locality of this species.

Platyteichum johnstonei Dickins?

Plate 17, figs. 1–3

Description. A single specimen similar in general shape to *Platyteichum johnstonei* but distinguished by having the whorl cross-section slightly more symmetrical so that the spire is more step-like. A narrow umbilicus penetrates between the whorls. The character of the slit-band and the ornament is similar to that of *P. johnstonei.*

Dimensions (in mm.)

	Height	*Width*	*Apical angle*	*No. of lirae above slit-band on last whorl*	*No. of lirae below slit-band on last whorl*
CPC109 . .	27 (approx.)	20	70°	9	About 29

Occurrence. Figured specimen (CPC109), Registered No. F17,076, 1¾ miles south-east of Muderong Bore, Middalya Station, from the Coolkilya Greywacke.

Discussion. Because of the difference in shape and the presence of an umbilicus it seems best to separate provisionally this specimen from *P. johnstonei*, although additional specimens may show that it is only a variety. The specimen is preserved as a limonitic replacement and the umbilicus may be open because the callus is not preserved.

Both *P. johnstonei* and *P. johnstonei?* somewhat resemble *Pleurotomaria timorensis* Wanner (1922, p. 20, pl. 151 (1), figs. 9*a–b*) from the Permian Basleo Beds of Timor. In *Pleurotomaria timorensis*, however, the step-like character of the spire is strongly developed and it does not seem possible to include it in *Platyteichum* unless a rather wide meaning is given to the genus.

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[1] CPC—Commonwealth Palaeontological Collection, Canberra; UWA—University of Western Australia Collection.

Platyteichum? sp. nov.

Plate 17, figs. 7–8

Description. The spire is of moderate height, with five whorls in mature specimens. The sutures are shallow but distinct. The slit-band is situated slightly above the periphery, the suture lying slightly but definitely below the slit-band. The whorl cross-section is gently convex except immediately below the suture, where it is flat or concave for a short distance as it rises to the previous whorl; it is sufficiently symmetrical to give a stepped character to the spire. The ornament comprises spiral and transverse elements and is similar to that of *P. johnstonei* except that there are more spiral lirae. The spiral lirae are of about equal prominence and the lirae bounding the slit-band are similar or only slightly more prominent than the others. The growth-lines are similar to those in *P. johnstonei.* In mature specimens the umbilicus was probably almost filled with callus, leaving only a small external umbilicus. The early whorls of all the specimens are poorly preserved.

Dimensions (in mm.)

	Height	*Width*	*Apical angle*	*No. of lirae above slit-band on last whorl*	*No. of lirae below slit-band on last whorl*
Figured Specimen A	19 (approx.)	20	84°	11	23+
Figured Specimen B	22 (approx.)	23	74°	About 15	. .
CPC112 . .	22	24 (approx.)	. .	About 12	. .

Occurrence. Figured Specimen A (CPC110), lat. 24° 22′ 26″ S., long. 115° 10′ 00″, 4·5 miles west of south of Merlinleigh Homestead, 97 feet above base of Norton Greywacke. Figured Specimen B (CPC111), lat. 24° 51′ 21″ S., long. 115° 10′ 53″, 3¼ miles from K38 on a bearing of 197° and 5 miles from Walbarune Peak (K40) on a bearing of 340°, Coolkilya Greywacke, 108 feet above base. CPC112, 1¾ miles south-east of Muderong Bore, Middalya Station, from Coolkilya Greywacke. One specimen from near Merlinleigh, four specimens from near K38, and two specimens from near Muderong Bore.

Discussion. In the ornament and the general character of the spire *P.?* sp. nov. is similar to *P. johnstonei.* It differs particularly, however, in the lesser proportion of the length to width, the greater number of spiral lirae and the greater symmetry of the whorl cross-

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EXPLANATION OF PLATE 17

Figs. 1–3. *Platyteichum johnstonei* Dickins?, three views CPC109, ×1.

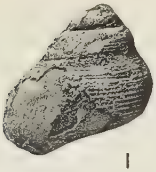
Figs. 4–6. *Platyteichum costatum* Campbell 1953, Queensland University Museum (QUM) F14,181, three views of the holotype, ×1.

Figs. 7–8. *Platyteichum?* sp. nov., ×1. 7, Figured specimen A, CPC110. 8, Figured specimen B, CPC111.

Figs. 9–12. *Platyteichum johnstonei* sp. nov. 9, Holotype, CPC108, ×2. 10–11, Two views of Paratype B, UWA42,116, ×1. 12, Paratype A, UWA42,115, ×1.

Figs. 13–14. *Platyteichum coniforme* (Etheridge jun.) 1892, Queensland Museum No. F17/1220, two views of holotype, ×2.

Figs. 15–19. *Atomodesma* (*Atomodesma*) *bisulcata* sp. nov., ×1. 15, Paratype B, QUM F27,122. 16, 18–19, Holotype QUM F27,124, lateral, anterior and dorsal views. 17, Paratype A, QUM27,121.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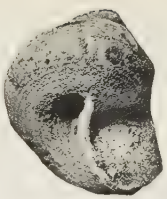
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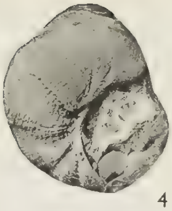
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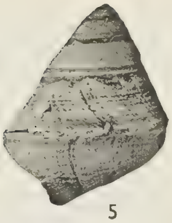
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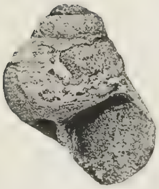
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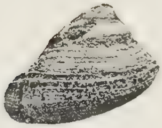
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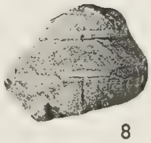
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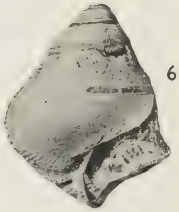
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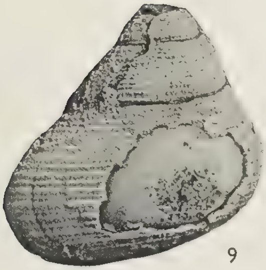
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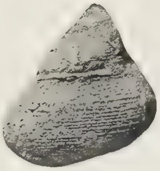
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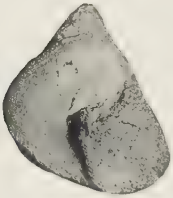
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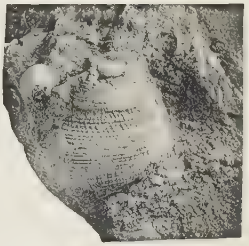
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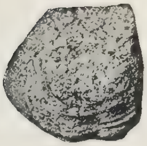
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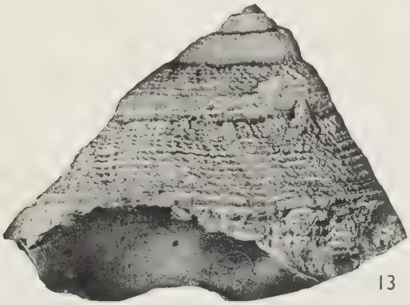
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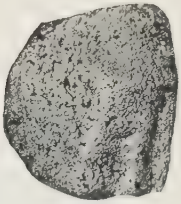
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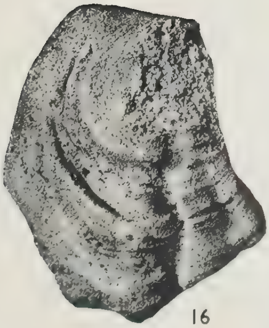
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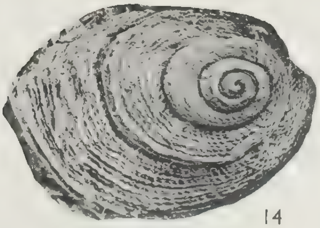
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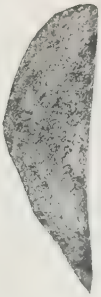
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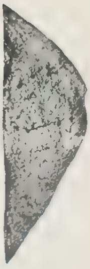
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DICKINS, *Platyteichum*

section which makes the spire distinctly step-like. Whether these differences are important taxonomically or are variable features within this group of shells is not clear from the present material. The differences of these shells from the type species of *Platyteichum* are such that I hesitate to place them positively in the same genus. I do not consider the material adequate for the erection of a specific name and the choice of type specimens.

In shape *P.?* sp. nov. somewhat resembles *Pleurotomaria conglobata* Wanner, Hamlet (1928, pl. 11, figs. 3*a–c*) from the Permian of Wesleoe, Timor. Hamlet's figured specimen, however, is slightly more step-like and the number of spiral ribs is not clear. It does not closely resemble Wanner's figured specimen of *Pleurotomaria conglobata* (1922, pl. 151 (1), fig. 10).

Acknowledgements. Part of this work was carried out in the Department of Geology of the University of Queensland in partial fulfilment of the requirements for the Ph.D. degree. Mr. G. Mack, Director, and Mr. J. T. Woods of the Queensland Museum are thanked for making specimens available for study, and the co-operation of Mr. F. S. Colliver and Mr. J. M. Lindsay, Curators of the Geological Museums at the Queensland and Western Australian Universities respectively, is gratefully acknowledged. The paper is published by permission of the Director of the Bureau of Mineral Resources, Geology and Geophysics.

REFERENCES

CAMPBELL, K. S. W. 1953. The fauna of the Permo-Carboniferous Ingelara Beds of Queensland. *Univ. Qld. Pap. Dep. Geol.* **4** (3), 1–30.

DICKINS, J. M. 1961. *Eurydesma* and *Peruvispira* from the Dwyka Beds of South Africa. *Palaeontology*, **4** (1).

DICKINS, J. M. and THOMAS, G. A. 1959. The marine fauna of the Lyons Group and the Carrandibby Shale of the Carnarvon Basin, Western Australia. *Bur. Min. Resour. Aust. Rep.* **38.**

ETHERIDGE, R., jun. 1892. *In* JACK, R. L. and ETHERIDGE, R., jun., *Geology and Palaeontology of Queensland and New Guinea.* Brisbane and London.

FLETCHER, H. O. 1945. A new genus *Glyptoleda* and revision of the genus *Nuculana* from the Permian of Australia. *Rec. Aust. Mus.* **21,** 293–312.

—— 1958. The Permian gastropods of New South Wales. Ibid. **24** (10), 115–64.

GLOVER, J. J. E. 1959. New names in Queensland stratigraphy: Permian of the south-eastern part of the Bowen Syncline. *Aust. Oil Gas J.* **5** (8), 30.

HAMLET, B. 1928. Permische Brachiopoden, Lamellibranchiaten und Gastropoden von Timor. *Jaarb. Mijnw. Ned.-Oost-Ind.* **56** (2), 1–115.

HILL, D. 1955. Contributions to the correlation and fauna of the Permian in Australia and New Zealand. *J. geol. Soc. Aust.* **2,** 83–107.

—— 1957. Explanatory notes, Springsure 4-mile Geological Series. *Bur. Min. Resour. Aust. Note Ser.* **5.**

REED, F. R. C. 1932. New fossils from the Agglomeratic Slate of Kashmir. *Palaeont. Indica*, N.S. **20,** 1.

TEICHERT, C. 1941. Upper Palaeozoic of Western Australia: correlation and palaeogeography. *Bull. Amer. Ass. Petrol. Geol.* **25,** 371–415.

THOMAS, G. A. and DICKINS, J. M. 1954. Correlations and age of the marine Permian formations of Western Australia. *Aust. J. Sci.* **16** (6), 219–23.

WANNER, C. 1922. Die Gastropoden und Lamellibranchiaten der Dyas von Timor. *Paläont. Timor*, **11** (18).

WEBB, E. A. 1956. Review of exploratory oil wells penetrating Permian sections in Central Queensland, Australia. *Bull. Amer. Ass. Petrol. Geol.* **40** (10), 2329–53 (reprinted in *Aust. Oil Gas J.* **3** (7), 3–22, 1957).

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EURYDESMA AND *PERUVISPIRA* FROM THE DWYKA BEDS OF SOUTH AFRICA

by J. M. DICKINS

ABSTRACT. *Eurydesma mytiloides* Reed 1932 and *Peruvispira vipersdorfensis* sp. nov. are described and figured. The distribution and origin of *Eurydesma* are considered. *Eurydesma* has been recorded from South Africa, India, Western and Eastern Australia, and South America: in all areas it is associated with deposits of glacial origin. It may have evolved from early Mytilacean forms and was apparently adapted to cold-water conditions and became extinct when these conditions ended. The characters of *Peruvispira* are discussed. It is separated from *Ptychomphalina* Fischer 1885, to which it is closely related, mainly by the possession of a distinct revolving concave area below the slit-band. *Pleurocinctosa* Fletcher 1958 is regarded as a synonym of *Peruvispira*. The fossils indicate a Lower Permian age, most likely Sakmarian but possibly early Artinskian.

ALTHOUGH the occurrence of *Eurydesma* in association with the Dwyka tillites was first recorded many years ago, up to the present no palaeontological description has been undertaken. As well as *Eurydesma* cf. *globosum* Dana,[1] Range (1912, p. 29–31, pl. 6) recorded conularians, fish, gastropods, and an *Inoceramus*-like pelecypod from beds he considered to be associated with the *Eurydesma* beds. Although the specimens figured by Range were too incomplete to allow definite identification at the species level, the hinge structure shown established the presence of *Eurydesma*.

Reed (1935, p. 161, pl. 5) described *Aphanaia haibensis* from the Upper Dwyka Shales near Haib, South-west Africa.

The present specimens were collected by Dr. H. Martin of the Geological Survey of South Africa and were forwarded for examination to Dr. C. Teichert, then at the Department of Geology, University of Melbourne. By arrangement with Dr. Teichert, Dr. Martin, and the Director of the Geological Survey of South Africa, the specimens were passed to the author for description.

The stratigraphical occurrence of the fossils is described in detail by Martin (1953). The marine invertebrate fossils are found in the Mariental–Keetmanshoop area, in the bottom part of the sequence, which lies discordantly on the Nama Beds. The Nama Beds are of Upper Precambrian to Lower Palaeozoic age (for a recent account see Haughton and Martin 1956). Martin shows that the layers with marine fossils are interbedded with deposits of glacial origin and of the total thickness of 1,400–1,700 feet he considers 800–1,000 feet to be glacial. The beds with marine fossils are separated by several hundred feet of shales from the *Mesosaurus* horizon.

In addition to the *Eurydesma*, which is described as *Eurydesma mytiloides* Reed, the collection contains *Peruvispira vipersdorfensis* sp. nov., an unidentified bryozoan and crinoid plates. Thus the occurrence in South Africa of elements of the '*Eurydesma*-fauna' other than *Eurydesma* (elements which are characteristically developed in India and in Western and Eastern Australia) is of considerable interest.

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[1] Etheridge and Dun (1910, p. 72) regard the specimens on which Dana based his description of *Eurydesma globosum* as young of *E. cordatum* and thus *E. globosum* is placed by them in synonymy. There certainly seems ample justification for Etheridge and Dun's conclusion.

[Palaeontology, Vol. 4, Part 1, 1961, pp. 138–148, pl. 18.]

WORLD DISTRIBUTION AND ORIGIN OF *EURYDESMA*

Eurydesma is known to occur in South Africa, India, Western and Eastern Australia, and South America. In all these areas it is associated with sediments showing marked signs of glacial influence. The author has recently discussed (1957, p. 18) the association of *Eurydesma* with cold, shallow-water sediments and taking into consideration the recent work on turbidity currents and deep-water deposition, there appears no reason to revise the conclusions made.

The origin of *Eurydesma* remains almost as obscure as when the subject was discussed by Etheridge and Dun in their classic monograph of 1910. Despite a wide search, no close ancestor is apparent in the Carboniferous Period. The relationship of *Eurydesma* to the living pteriids is not as close as was thought by Etheridge and Dun. *Eurydesma* differs especially from all other forms in its marked dental process at the anterior end of the hinge, in the anterior position of a large adductor muscle and in the S-shaped series of muscle pits associated with the umbo. These impressions probably represent the pedal muscles and the pits of the pallial attachment. Waagen (1891, p. 140, pl. 6, figs. 3–6) suggests real cardinal teeth are present but these may represent rather folds of shelly material not analogous with hinge-teeth. Koken (1904, p. 101) says no such teeth are visible in his specimens from the Salt Range and I have never observed them in specimens from Australia. The ligament, which is lodged in a single elongated ligament groove, is of a type common in many groups of Palaeozoic shells, a type which has apparently formed the basis of that found in living mytilids. The ligament, the dental process, and the relatively complex shell structure (see Dickins 1957) would preclude close relationship to the living Pteriidae. The distinctiveness of *Eurydesma* from other late Palaeozoic pelecypods is emphasized by its arrangement in a separate family, Eurydesmidae Reed.

Amongst earlier forms, *Eurydesma* appears to resemble *Shaninopsis* Isberg (1934, p. 336) from the Leptaenakalkes of Dalarna (Ordovician to Silurian). *Shaninopsis* has the same type of ligament, is similar in shape, and has a dental process not unlike that found in *Eurydesma*. It differs, however, in possessing a distinct anterior byssal opening. As such a long period of time separates *Shaninopsis* from *Eurydesma*, an alternative explanation to descent of *Eurydesma* from *Shaninopsis* may be that *Eurydesma* developed rapidly, probably from one of the Mytilacea, in the environment which came into existence towards the end of the Carboniferous Period. *Eurydesma* can be related to the Mytilacea in the following respects:

1. The shell structure, although differing from the Myalinidae, is not very different from that described by Newell (1942, p. 32) in the Mytilidae.
2. The ligament is of the same type as that found in *Atomodesma* which has been placed in the family Myalinidae (Newell 1942, and other authors).
3. The pattern of the pedal muscle scars and the pits of the pallial attachment would require only slight modification from that found in the Myalinidae. A similar muscle pattern, however, also occurs in the Pteriacea.
4. The dental process could be derived from the umbonal septum found in *Atomodesma*, and in other genera of Myalinidae. The Myalinidae, however, appear to lack the distinct byssal notch found in front of the dental process of the right valve of *Eurydesma*. The byssal notch is especially distinct in young *Eurydesma*.

It thus seems possible that *Eurydesma* developed rapidly in cold-water conditions, either accompanying or immediately after the late Palaeozoic glaciation. Once developed it became stabilized to these conditions and very little evolutionary development is apparent.

Any large collection of specimens made at one locality (collection point) shows considerable variation and some authors (Reed 1936; Harrington 1955; Sahni and Srivastava 1956) have proposed a considerable number of specific names in such cases. In samples I have examined, however, from Western Australia, New South Wales, and Queensland, there have been no sharp morphological differences which could be used for specific differentiation and the whole appeared to be rather a single variable community. This variability has already been noted by a number of previous workers, including Etheridge and Dun (1910, pp. 47, 72), Fossa Mancini (1944, p. 91—*fide* Harrington 1955, p. 122) and Harrington (1955, p. 122). Many of the groups for which specific names have been proposed, therefore, should possibly be regarded rather as varieties. As frequently occurs with variable forms there seems to be considerable stratigraphical and geographical range of species, and the species found in different regions do not differ greatly.

When the conditions to which *Eurydesma* was apparently specially adapted ceased to exist the genus rapidly became extinct. In Western Australia and Salt Range, India, this occurred in late Sakmarian or early Artinskian time, when the Gondwana '*Eurydesma*-fauna' was replaced, in the Lower Productus Limestone and the Callytharra Formation, respectively, by a more temperate Tethyan Fauna (Dickins 1957; Dickins and Thomas 1959). It is possible that in the Agglomeratic Slate of Kashmir *Eurydesma* lingered on slightly longer. In Eastern Australia, which was apparently partly isolated, either by climate or by geography, the earlier fauna persists with considerable diversification until at least late Lower Permian (Kungurian),[1] when earth movements brought marine sedimentation to an end and initiated extensive intra-continental non-marine deposition. *Eurydesma* itself, however, does not appear to persist to the top of the marine sequence.

AGE OF THE DWYKA FAUNA

To the marine forms previously recorded (conulariids, '*Aphanaia*' *haibensis* Reed 1935, unidentified gastropods and pelecypods and fish remains) can be added *Eurydesma mytiloides* Reed 1932 and *Peruvispira vipersdorfensis* sp. nov. which are described in the present paper. Amongst the molluscs *E. mytiloides* and *P. vipersdorfensis* are important with regard to the age of the South African deposits, as pelecypods similar to '*Aphanaia*' *haibensis* are known to occur in the Lower and Upper Permian of both North-eastern Siberia (Popov, 1957) and Western Australia (unpublished work of the author).

Du Toit (1954, p. 356) apparently considered that the horizons with marine fossils lay above the glacial deposits and concluded that the Dwyka ice age must have embraced much, if not the whole, of the Upper Carboniferous, while the Upper Dwyka shales (with *Eurydesma*) were not younger than lowest Permian. Martin's (1953) work, however, indicates that marine horizons are interbedded with the glacial horizons. Martin (written communication) considers it probable also that *Eurydesma* occurs in shales overlying the highest glacial bed. The affinities of the marine fossils would suggest they are of a Lower Permian age, mostly likely Sakmarian but possibly early Artinskian.

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[1] General although not unanimous current Soviet opinion is followed with regard to the subdivision of the Permian System. The System is regarded as containing two main subdivisions, Lower and Upper, the Lower comprising the Sakmarian, Artinskian, and Kungurian Stages and the Upper, Kazanian and Tatarian (Kulikov, pers. comm.; and Stepanov 1958). The Australian deposits are correlated with the standard subdivisions and the names are used to indicate the age.

Some workers have concluded, for example Caster (1953), Beurlen (1953), Maack (1957), and Putzer (1957), that the '*Glossopteris* flora' of South America associated with deposits of glacial origin and marine fossils is of Upper Carboniferous age. To some extent this seems to be based on the assumption that the Australian '*Glossopteris* (and *Gangamopteris*) flora' and the '*Eurydesma* fauna' are of Upper Carboniferous age. Dickins and Thomas (1959) have considered evidence which indicates that in Australia the '*Eurydesma* fauna' with associated glacials is mainly or entirely of Lower Permian age. If the '*Eurydesma* fauna' does begin earlier, which we do not think likely, it could only be in the very uppermost Carboniferous. If our conclusion is correct then it follows also that the '*Glossopteris* flora' first appears in the Lower Permian or less likely in the very uppermost Carboniferous because we do not know of any occurrence of the '*Glossopteris* flora' in Australia significantly earlier than *Eurydesma*.

In New South Wales evidence has been adduced for Carboniferous glaciation earlier than that associated with the '*Eurydesma* fauna' (see David 1950, p. 292). This earlier glaciation appears to be confined to New South Wales and may be associated with Upper Carboniferous orogeny. In India also, some workers, for example Bhatia and Singh (1959), had made a similar assumption that the '*Eurydesma* fauna' is Upper Carboniferous and have used this to support a conclusion that Talchir Series is of Upper Carboniferous age. The evidence from New South Wales for glaciation both in the Carboniferous and in the Lower Permian may have caused confusion with regard to the stratigraphical position and age of the '*Eurydesma* fauna'. Bhatia and Singh have also indicated that the arenaceous forams from the Talchir Series are similar to those of the Pennsylvanian of North America. They are similar also, however, to forms found in the Permian of Western Australia (see Crespin 1958). Although the possibility that the '*Eurydesma* fauna' first appeared in the uppermost Carboniferous cannot be discarded, the close relationship of the South African fossils to forms from Kashmir, Umaria, the Salt Range, and Western Australia indicates a Lower Permian age (Sakmarian or possibly early Artinskian).

E. mytiloides has so far been recorded from the Agglomeratic Slate of Kashmir and the Speckled Sandstone of the Salt Range, from Argentina, and recently by Sahni and Srivastava (1956) from the eastern Himalayas. Harrington, who described the Argentinian species, has also suggested (1955, p. 124) that a specimen from Eastern Australia referred to *Eurydesma cordatum* var. *sacculum* by Etheridge and Dun may belong to *E. mytiloides*. I have recently suggested (Dickins and Thomas 1959) that *E. mytiloides* may be present at Umaria, from where *P. umariensis*, which is closely related to *P. vipersdorfensis*, was first described.

Dickins and Thomas, on the basis of the occurrence of similar productids and spiriferids, the gastropod *P. umariensis*, and a calceolispongiid crinoid, correlate the Umaria Beds with the upper part of the Lyons Group, considering both to be of Sakmarian age. The Speckled Sandstone on the basis of its brachiopods and molluscs is also considered to be of similar age. Both the Umaria Beds and the Speckled Sandstone lie above or at the top of the Talchir Series. The Agglomeratic Slate of Kashmir, on the basis especially of the molluscs, productids, and spiriferids, as well as probably containing sediments of Sakmarian age, may also contain slightly younger sediments as the sequence contains *Oriocrassatella* and a type of *Deltopecten* which, in Western Australia, appear in formations younger than Lyons Group and which are not recorded from the Umaria Beds and the Speckled Sandstone.

As is considered in more detail later, *P. vipersdorfensis* appears to resemble the older (Sakmarian) species of *Peruvispira* more closely than the younger Artinskian.

The conclusion made about the age of the Dwyka Beds is similar to that of Gürich (1923, p. 73) who described the fish from Ganikobis and considered they were late Carboniferous or early Permian. Recently Leschik has described spores from beds overlying the *Eurydesma* horizon and underlying the *Mesosaurus* horizon; he regards the spore-bearing beds as Lower Permian (1959, p. 52).

SYSTEMATIC DESCRIPTIONS

Class PELECYPODA

Family EURYDESMIDAE Reed 1932

Genus EURYDESMA Morris 1845

Type species. Eurydesma cordata Morris (1845, p. 276, pl. 12, figs. 1, 2) by monotypy.

Eurydesma mytiloides Reed 1932

Plate 18, figs. 1–6

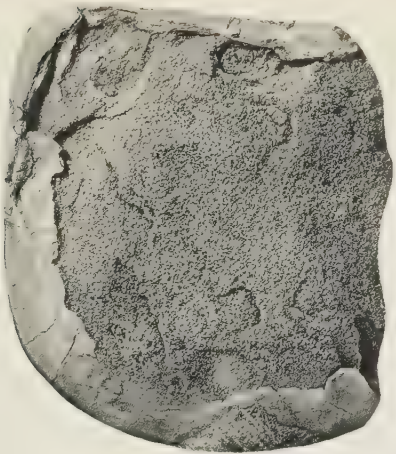
1932 *Eurydesma cordatum* Morris var. *mytiloides* Reed, p. 50, pl. 11, figs. 1–3*b*.
1936 *Eurydesma cordatum* Morris var. *mytiloides* Reed 1932; Reed, p. 18, pl. 3, figs. 1, 2.
1955 *Eurydesma mytiloides* Reed 1932; Harrington, p. 124, pl. 25, figs. 5–8.
1956 *Eurydesma cordatum* Morris var. *mytiloides* Reed 1932; Sahni and Srivastava, p. 205, pl. 34, figs. 1–3.

Description. The shells are oval and of moderate size for *Eurydesma*. The ligament is characteristic of *Eurydesma*, lodged in an elongated groove running backwards from the umbo and narrowing toward both front and back. Fine longitudinal growth-lines are visible within the ligament groove. In the right valve the distinct byssal notch runs almost directly downwards, but is inclined slightly towards the back. The details of the dental process in the right valve are obscured by erosion. In the left valve the characteristic smaller process is developed at the anterior end of the hinge-line. When the two valves are in position the process of the left valve overlaps the right valve and covers from view the byssal opening (see Etheridge and Dun 1910, pl. 18, fig. 3; pl. 19, fig. 3;

EXPLANATION OF PLATE 18

Figs. 1–6. *Eurydesma mytiloides* Reed 1932. All specimens figured are from Farm Hardap 110, about 10 miles north-west of Mariental. 1, Hypotype C, left valve, No. 7093, lateral view, ×1. 2, Hypotype A, right valve, No. 7087, internal view showing the hinge, ×1; the hinge is damaged by weathering. 3, Hypotype B, left valve, No. 7094, internal view showing hinge, ×1; the back part of the shell is missing. 4, Hypotype E, right valve, No. 7090, dorsal view, ×1. 5, 6, Hypotype D, bivalved specimen, No. 7086, lateral view of left valve and front view respectively, ×½; the specimen is crushed and telescoped in a dorso-ventral direction so that the shape is distorted.

Figs. 7–11. *Peruvispira vipersdorfensis* sp. nov. ×4. All specimens figured have the number 7081 and are from Farm Vipersdorf No. 63, Gibeon District. 7, Holotype, external matrix blotted out to show character of slit-band and concave revolving area. 8, Holotype showing shell in matrix. 9, Paratype B. 10, Paratype A. 11, Paratype C.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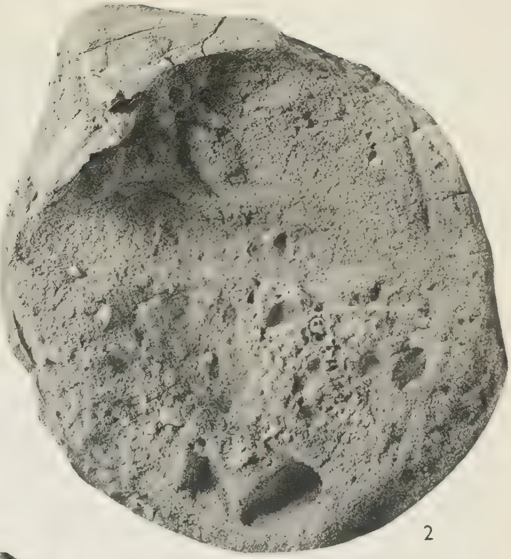
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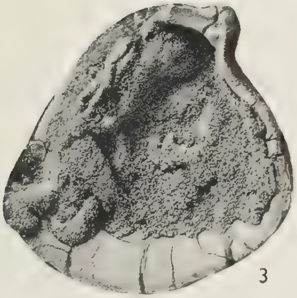
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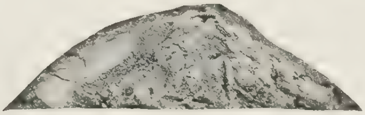
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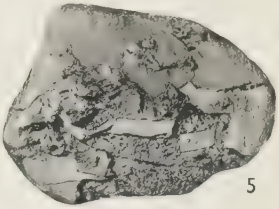
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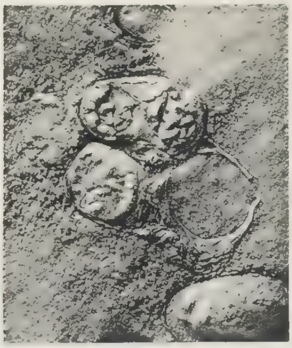
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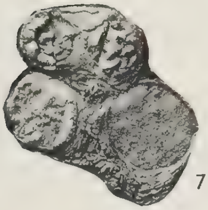
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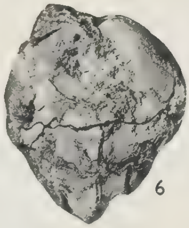
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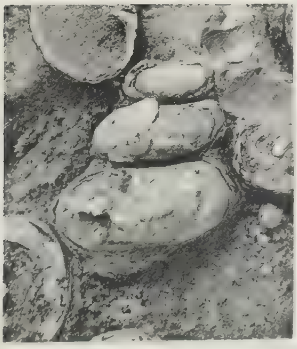
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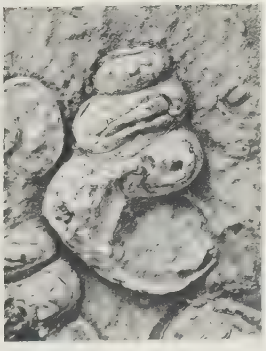
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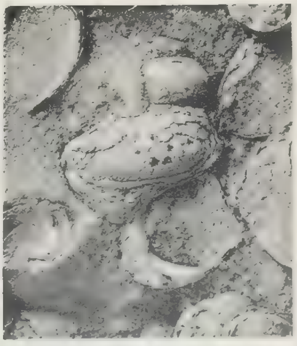
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DICKINS, *Eurydesma* and *Peruvispira*

Dickins 1957, pl. 5, fig. 11). The external surface is ornamented only with concentric growth-lines. A distinct lobe is formed anteriorly and the umbo is developed in a similar manner to described specimens of *E. mytiloides*. The umbo appears to be more distinctly developed than in *E. playfordi* Dickins (1957, p. 33, pl. 5, figs. 1–11). The muscle pattern is not visible in any of the specimens.

Dimensions (in mm.)

	Length	*Height*	*Thickness*
Hypotype A (7087): right valve . .	68	70	. .
Hypotype B (7094): left valve . .	35 (approx.)	36	. .
Hypotype C (7093): left valve . .	52 (approx.)	55	16
Hypotype D (7086): bivalved specimen .	Crushing does not allow reliable measurement		
Hypotype E (7090): right valve . .	50	52 (approx.)	15

Occurrence. All the specimens come from the lower part of the Dwyka Succession, Farm Hardap 110 about 10 miles north-west of Mariental. The numbers are those of the Geological Survey, Union of South Africa, Pretoria, where the specimens are housed.

Discussion. Taking into consideration the specimens available there does not seem to be any basis for their separation from *A. mytiloides* Reed. Range figured two umbonal fragments similar to the umbonal parts of Martin's specimens, and they seem likely to belong to the same species. The reference of Range's specimens to *E.* cf. *globosum* Dana by Professor Schröder (Range 1912, p. 29) was reasonable at the time, before Reed's description of the Kashmir fauna became available, but the South African specimens are distinct from those of *E. globosum* (= young specimens of *E. cordatum*). The young specimen figured by Dana (1847, pl. 7, figs. 7; 7*a*) shows already the very tumid and prominent umbo characteristic of *E. cordatum*.

When proposing the name *E. cordata* Morris (1845, p. 276) figured two shells. Apparently neither has been chosen as a type and if this is the case, the top figure of pl. 12, apparently fig. 1, is here designated as the lectotype. This designation safeguards usage and meets the suggestion of Etheridge and Dun (1910, p. 72): 'The large number of specimens now before us conforming to Morris's upper single figure, compels us to regard this as representing the type form of *E. cordatum*.'

Morris states that his specimens are from Illawarra, New South Wales, but as with his specimens of *Deltopecten illawarrensis* there must be doubt whether this locality is correct (see Etheridge and Dun 1910, p. 69). It seems likely that Morris's specimens came from Harpers Hill where *E. cordatum* is common and from where he also had specimens.

I am grateful for the following comment to Mr. S. Ware of the British Museum (Natural History) where Morris's specimens are housed: 'The two specimens of *E. cordata* in question have a preservation entirely different from the other six specimens from Illawarra. *E. cordata* (pl. 12, fig. 1) is identical with our material from Harpers Hill, and the other (pl. 12, fig. 2) compares most favourably with specimens preserved in a black or greyish black limestone labelled '? W. Maitland' unfortunately, and also *Eurydesma* specimens from Tasmania.'

E. mytiloides is so different from *E. cordatum* especially with respect to the characters of the umbo that I have no hesitation in agreeing with Harrington's (1955, p. 124) decision to regard Reed's variety as a species.

Class GASTROPODA

Family PLEUROTOMARIIDAE D'Orbigny

Genus PERUVISPIRA Chronic 1949

Type species. Peruvispira delicata Chronic (*in* Newell, Chronic, and Roberts 1949, p. 147; 1953, p. 139, pl. 28, figs. 9–12) by original designation of Chronic.

Synonym. Pleurocinctosa Fletcher (1958, p. 139).

Diagnosis. Similar to *Ptychomphalina* Fischer 1885 but characterized by the possession of a distinct revolving concave area about as wide as and below the slit-band. The concave area is bounded below by a ridge which may form a lira or carina. The growth-lines after leaving the base of the slit-band swing forward across the concave area and then back across the revolving ridge and over the base of the whorl.

Family position. Because of the variability of certain important characters and thus the difficulty of choosing distinct groupings, the supra-specific subdivision of the Upper Palaeozoic pleurotomarioids presents considerable difficulties. The taxonomy of the family level is under review (see Batten 1958, p. 184) and in this paper *Peruvispira* is retained in the family Pleurotomariidae. This, however, must be regarded as provisional only.

Discussion. Although all the described species of *Peruvispira* have a higher spire than is found in the type species of *Ptychomphalina P. striata* (J. Sowerby) (figured and described in Knight 1941, p. 286, pl. 29, figs. 3*a*–*c*), such a difference alone can hardly be regarded as a reliable criterion for generic distinction. The spire will vary in height according to small variations in the whorl profile and the amount of involution, and indeed varies considerably within some ptychomphalinid species that I have examined. In *Peruvispira* the whorl cross-section in a general way is similar to that of the type species of *Ptychomphalina*, and the differences in detail, except for the occurrence of the distinct concave area below the slit-band, would not appear to warrant generic separation.

In proposing the generic name *Peruvispira* Chronic made no comparison of his new genus with *Ptychomphalina*; perhaps he assumed, following Thomas (1940), that it was a synonym of *Mourlonia*. On the other hand *Peruvispira* does not appear to be particularly closely related to *Neilsonia* Thomas (1940). Thomas based her conclusion regarding the synonymy of *Ptychomphalina* not on examination of the type specimens but on Fischer's (1885) description of *Ptychomphalina* where it is stated that *Ptychomphalina* has spiral ornament. However, according to Knight's (1941) description and figures, *Ptychomphalina* can be separated from *Mourlonia* by its lack of spiral ornament. None of the Western Australian Permian species referable to *Ptychomphalina* has any spiral ornament; this character appears to be consistent and of some importance. *Ptychomphalina* also, according to Knight, has a distinct thickening of the columellar lip without an extension of callus outside the aperture and the Mourlonias and Ptychomphalinas form two distinct lines of development in the Carboniferous and Permian; so that, although the two lines may be convergent in the Lower Carboniferous, it does not seem justifiable to place *Ptychomphalina* in synonymy with *Mourlonia*.

In *Ptychomphalina striata* (J. Sowerby), as figured in Knight (1941), the growth-lines swing forward only slightly below the slit-band, and a narrow poorly developed concave area is present. Thus although *Peruvispira* is distinguished only by the degree of development of these features, its recognition as a separate taxonomic group appears justifiable because it forms a rather compact group of high-spired forms which has a different stratigraphical distribution from *Ptychomphalina*.

Fletcher (1958, p. 139) has proposed the new generic name *Pleurocinctosa*, with *Pleurotomaria trifilata* Dana (1847, p. 150) as the type species. He distinguishes *Pleurocinctosa* from *Peruvispira* on the possession of a strongly developed columellar lip and other apertural features. However, in the specimens of *Peruvispira* figured by Chronic (*in* Newell, Chronic, and Roberts 1953, pl. 28, figs. 9–12) the columellar lip seems to be incompletely preserved, so that proposal of a new name on the basis of the apertural features seems hardly justifiable. In other important characters such as whorl height and profile, nature of the slit-band, ornamentation, and the concave revolving area beneath the slit-band *Peruvispira* and *Pleurocinctosa* are similar. It seems unlikely that, when complete specimens of *Peruvispira delicata* are available, the apertural features will differ in any important way from those of *Pleurotomaria trifilata*; so I have no hesitation in regarding *Pleurocinctosa* as a synonym of *Peruvispira*.

Peruvispira vipersdorfensis sp. nov.

Plate 18, figs. 7–11

Diagnosis. Very similar to *Peruvispira trifilata* (Dana)[1] (1847, p. 150; 1849, p. 706, pl. 9, figs. 15, 15*a*) and *Peruvispira umariensis* (Reed) (1928, p. 389, pl. 34, fig. 12, pl. 35, figs. 11–13). Separated, however, from *P. umariensis* by having a less well-rounded whorl cross-section and having the third lira or ridge situated farther away from the periphery of the shell. From *P. trifilata* it can be separated by the higher spire and the lesser apical angle.

Description. Holotype: a natural vertical cross-section through the columella, slightly etched with acetic acid, shows the essential features of the species. The upper whorl surface is almost straight with the slit-band at the outer edge and approximately vertical. The slit-band is bounded on either side by a distinct ridge. Below the slit-band the outline is concave; the concave part being bounded below by a ridge. The outline then joins the base with an arc of low curvature. The columellar lip is distinctly thickened as in *P. umariensis* and *P. trifilata*. Other specimens: these confirm the characters shown by the holotype. Paratype B shows in addition that the adult was non-umbilicate. Apparently most mature specimens have four whorls, though some have five.

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[1] Fletcher (1958, p. 140) sets out reasons for considering that *Pleurotomaria morrisiana* M'Coy (1847, p. 306, pl. 17, fig. 5) should be regarded as a synonym of *Pleurotomaria trifilata*. The choice by Fletcher of the specimen figured by Dana (1849, pl. 9, figs. 15, 15*a*) as the holotype thus ensures that *P. morrisiana* becomes a synonym of *P. trifilata*. The writer is in full accord with the proposals and conclusions of Fletcher in this regard.

Dimensions (in mm.)

	Height	*Width*	*Apical angle*
Holotype . .	9 (approx.)	6	46°
Paratype A . .	8 (approx.)	6	45°
Paratype B . .	8	5·5	38°
Paratype C . .	9	6	38°

Occurrence. Holotype and Paratypes A, B, and C, No. 7081, Farm Vipersdorf No. 63, Gibeon District, other specimens No. 7082, Tses Native Reserve, near main road about 8 miles north of Tses Siding. The numbers are those of the Geological Survey, Union of South Africa, Pretoria, where the specimens are housed.

Discussion. Although several pieces of rock are crowded with some hundreds of specimens apparently all belonging to this species, only a few specimens show the characters necessary for a generic and specific differentiation. The preservation is not good, but revolving ornament appears to be present only as ridges bounding the slit-band and the ridge at the lower boundary of the revolving concave area.

Whorl cross-section and the height of the spire vary somewhat, so that some specimens approach more closely to *P. trifilata* and others to *P. umariensis*. On the whole, however, the species appears to approach closer to *P. umariensis* than to *P. trifilata* and it is tempting to identify specimens with more rounded whorls with *P. umariensis*. It seems best, for the present at least, to recognize the overall difference of the South African specimens as a specific difference.

P. vipersdorfensis also appears to be closely related to *Peruvispira allandalensis* (Fletcher) (1958, p. 141, pl. 11, figs. 7–9, pl. 12, figs. 2, 3) from the Lochinvar and Allandale 'Formations' of the Lower Marine Beds (= Dalwood Group of Hanlon *in* Hill 1955) of the Hunter Valley, New South Wales. *P. allandalensis* apparently has a greater number of whorls, a higher spire, and an overall lesser apical angle. *P. vipersdorfensis* appears to be more closely related to the slightly older forms, *P. umariensis* and *P. allandalensis* which occur in rocks of Sakmarian (Lower Permian) age than to the younger *P. trifilata* which occurs in rocks of Artinskian (Lower Permian) age.

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REFERENCES

BATTEN, R. L. 1958. Permian Gastropoda of the South-western United States. 2. Pleurotomariacea: Portlockiellidae, Phymatopleuridae and Eotomariidae. *Bull. Amer. Mus. nat. Hist.* **114** (2).

BEURLEN, K. 1953. Einige vorläufige Mitteilungen über die Stratigraphie des Gondwana-Systems. *Neues Jb. Geol. Paläont.*, Abh. **97** (1/3), 241–56.

BHATIA, S. B. and SINGH, S. K. 1959. Carboniferous (Uralian) Foraminifera from Manendragarth, Central India. *Micropaleontology*, **5** (1), 127–34.

CASTER, K. E. 1953. Stratigraphic and palaeontologic data relevant to the problem of Afro-American ligation during the Paleozoic and Mesozoic. *Bull. Amer. Mus. nat. Hist.* **99** (3), 105–52.

CRESPIN, C. 1958. Permian Foraminifera of Australia. *Bur. Min. Resour. Aust. Bull.* **48.**

DANA, J. D. 1847. Description of fossils from Australia. *Amer. J. Sci.* **54,** 151–60.

—— 1849. *In* United States Exploring Expedition during the years 1838–42 under the command of Charles Wilkes, U.S.N., 10, Geology, 681–713.

DAVID, T. W. E. *ed.* BROWNE, W. R. 1950. *The Geology of the Commonwealth of Australia*, Vol. 1, London.

DICKINS, J. M. 1957. Lower Permian Pelecypods and Gastropods from the Carnarvon Basin, Western Australia. *Bur. Min. Resour. Aust. Bull.* **41.**

DICKINS, J. M. and THOMAS, G. A. 1959. The marine fauna of the Lyons Group and the Carrandibby Shale of the Carnarvon Basin, Western Australia. *Bur. Min. Resour. Aust. Rep.* **38.**

ETHERIDGE, R. jun. and DUN, W. S. 1910. A monograph of the Carboniferous and Permo-carboniferous Invertebrata of N.S.W., Vol. II—Pelecypoda, Part II—*Eurydesma. Mem. geol. Surv. N.S.W., Palaeont.* **5,** 41–75.

FISCHER, P. 1880–7. *Manuel de conchyliologie et de paléontologie conchyliologique*, Paris.

FLETCHER, H. O. 1958. The Permian Gastropods of New South Wales. *Rec. Aust. Mus.* **24** (10), 115–64.

FOSSA MANCINI, E. 1944. Las transgresiones marinas del Antracolítico en América del Sur. *Rev. Mus. La Plata, sec. Geol.* **2,** No. 49 [not seen].

GÜRICH, G. 1923. *Acrolepis Lotzi* und andere Ganoiden aus den Dwyka-Schichten von Ganikobis Südwestafrika. *Beitr. geol. Erforsch. dtsch. SchGeb.* **19** (2), 26–74.

HARRINGTON, H. J. 1955. The Permian *Eurydesma* Fauna of Eastern Argentina. *J. Paleont.* **29,** 112–28.

HAUGHTON, S. H. and MARTIN, H. 1956. The Nama System in South and South-West Africa. *Congr. geol. int. xx sess.*, Mexico: Symp. Cambrian, **1,** 323–39.

HILL, D. 1955. Contributions to the correlation and fauna of the Permian in Australia and New Zealand. *J. geol. Soc. Aust.* **2,** 83–107.

ISBERG, O. 1934. *Studien über Lamellibranchiaten des Leptaenakalkes in Dalarna. Beitrag zu einer Orientierung über die Muschelfauna im Ordovicium und Silur.* Lund, Hakan Ohlssons Buchdruckerei.

KNIGHT, J. B. 1941. Paleozoic Gastropod Genotypes. *Spec. Pap. geol. Soc. Amer.* **32.**

KOKEN, E. 1904. Eurydesma und der Eurydesmen-Horizont in der Saltrange. *Zbl. Miner. Geol. Paläont.* **5,** 97–107.

LESCHIK, G. 1959. Sporen aus den 'Karru Sandsteinen' von Norronaub (Südwest-Afrika). *Senck. Leth.* **40** (1/2), 51–95.

MAACK, R. 1957. Über Vereisungsperioden und Vereisungsspuren in Brasilien. *Geol. Rdsch.* **45** (3), 547–94.

MCCOY, F. 1847. On the fossil botany and zoology of the rocks associated with coal of Australia. *Ann. Mag. nat. Hist.*, ser. 1, **20,** 145–57, 226–36, 298–312.

MARTIN, H. 1953. Notes on the Dwyka Succession and on some Pre-Dwyka valleys in South-West Africa. *Trans. geol. Soc. S. Afr.* **56,** 37–41.

MORRIS, J. 1845. Descriptions of fossils, *in* STRZELECKI, P. DE, *Physical description of New South Wales and Van Diemen's Land*, London, 270–91.

NEWELL, N. D. 1942. Late Paleozoic Pelecypods: Mytilacea. *Kansas geol. Surv.* **10** (2), 1–115.

NEWELL, N. D., CHRONIC, J., and ROBERTS, T. G. 1949. *Upper Paleozoic of Peru*, New York [not seen].

—— —— —— 1953. Upper Paleozoic of Peru. *Mem. geol. Soc. Amer.* **58.**

POPOV, U. N. 1957. Some Permian Pelecypods, Gastropods and Ammonites of Verchoyan. *Sci. Inst. Geol. Arctic, Coll. Pap. Palaeont. Biostrat.* **1,** 45–60 (also in *Mater. Geol. Min. Resour. N.E. U.S.S.R.*, 1958 (12)).

PUTZER, H. 1957. Beziehungen zwischen Inland-Vereisung und Kohlebildung im Oberkarbon von Süd-Brasilien. *Geol. Rdsch.* **45** (3), 599–608.

RANGE, P. 1912. Geologie des deutschen Namalandes. *Beitr. geol. Erforsch. dtsch. SchGeb.* **2.**

REED, F. R. C. 1928. A Permo-Carboniferous marine fauna from the Umaria Coal Field. *Rec. geol. Surv. India*, **60,** 367–98.

—— 1932. New fossils from the Agglomeratic Slate of Kashmir. *Paleont. Indica*, N.S. **20** (1).

REED, F. R. C. 1935. A new Lamellibranch from the Upper Dwyka Beds of South-West Africa. *Trans. roy. Soc. S. Afr.* **23,** 161–3.

—— 1936. Some fossils from the *Eurydesma* and *Conularia* Beds (Punjabian) of the Salt Range. *Palaeont. Indica,* N.S. **23** (1).

SAHNI, M. R. and SRIVASTAVA, J. P. 1956. Discovery of *Eurydesma* and *Conularia* in the Eastern Himalaya and description of associated faunas. *J. palaeont. Soc. India,* **1** (1), 202–14.

STEPANOV, D. L. 1958. The Carboniferous System and its main stratigraphic subdivisions—Report to the Commission on the Stratigraphy of the Carboniferous of the National Committee of Soviet Geologists. Copy distributed at Heerlen conference on Carboniferous stratigraphy, 1958.

THOMAS, E. G. 1940. Revision of the Scottish Carboniferous Pleurotomariidae. *Trans. geol. Soc. Glasgow,* **20** (1), 30–72.

TOIT, A. L. DU. 1954. *The Geology of South Africa.* Edinburgh and London.

WAAGEN, W. 1891. Salt Range fossils. *Palaeont. Indica,* ser. 13, **4** (2), 89–242.

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